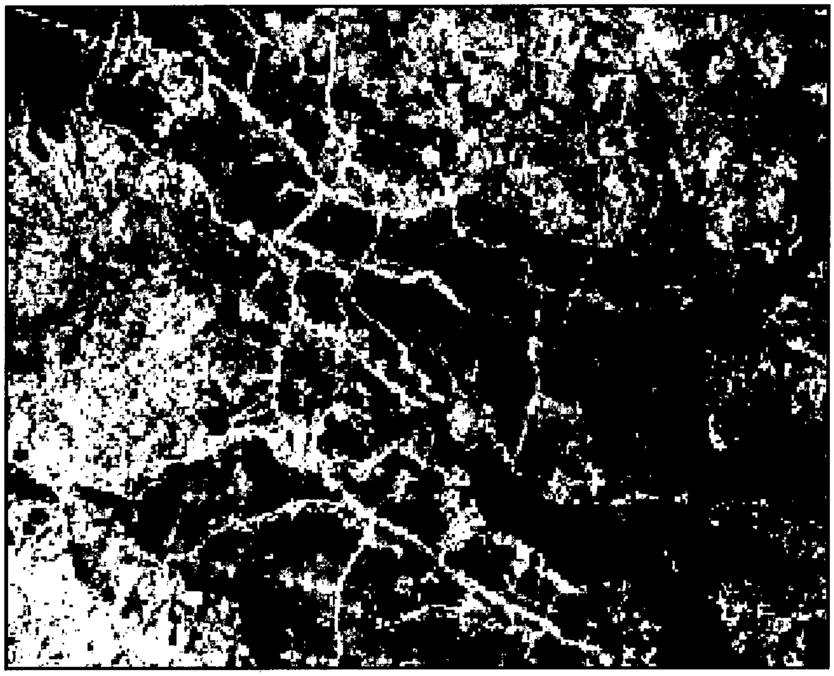
REMOTE SENSING USERS' GUIDE



Ft. Hood, Texas; 1989 TM scene

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Remote Sensing Users' Guide

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and
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EXECUTIVE SUMMARY

This document provides an organized guide to currently available and near-term remote sensors for land managers. Inexperienced as well as more advanced users can use this guide as a source of information and guidance in remote sensing decision making.

The *Selection Key,* contains three sections; vegetation, soils, and land management objectives. Each of the three sections is organized by ecoregion, allowing the user to identify the imagery capable of meeting their needs. Many of the management objectives within the keys contain references to applicable articles describing scientific investigations. These referenced articles can provide the resource manager with information and ideas of how to approach their management objectives.

Sensor Fact Sheets provide details on each sensor, and includes information on spatial resolution, band width, cost, revisit time, and other image characteristics. Sheets can be removed from the binder to allow side-by-side comparison of the sensors identified by the *Selection Key.*

Sample *Statements of Work* and sources of *Acquisition Assistance* are included. Land managers can use the examples given to help them procure imagery themselves or to determine if additional assistance is needed.

Brief explanatory sections cover the elements that make up a remotely sensed image, and how image interpreters use those elements to extract information from the image. There are also appendices, more appropriate for advanced users, that discuss spectral information and imagery sources. A bibliography lists the literature cited in the text and the *Selection Key.*

This guide will be successful if it helps resource managers better understand the nature of remotely sensed imagery, how to select specific sensors for specific tasks, decide whether to work independently or to use contractor expertise, find literature that discuss case studies similar to theirs, interpret historical imagery, and locate free or inexpensive imagery already owned by government agencies.

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I. INTRODUCTION

A. Guide Overview

1. Objective

This guide provides an organized tool to help land managers take advantage of existing remote sensing technology.

2. Included in this guide

- what remote sensing can do
- keys to help users select appropriate imagery
- Sensor Fact Sheets - details on sensors and samples of imagery
- Statements of Work (SOW) samples & procurement assistance information
- how image interpreters use texture, color, tone and shape to analyze images
- Advanced users' appendices on spectral information, imagery sources, and literature citations for further information

3. This guide provides tools to help users

- Better understand remote sensing's capabilities and limitations
- Determine which sensors can meet their needs and weigh other factors, such as cost, to make well-informed decisions
- Determine whether to proceed independently or use contractor expertise to order imagery or custom photo flights
- Find literature describing remote sensing uses similar to their needs
- Interpret archival (historical) imagery already available to resource managers
- Locate free or inexpensive imagery already acquired by federal agencies

This guide is the first of a possible series of regularly updated versions. Remote sensing technology, sensors, spaceborne platforms and applications are changing continuously. We hope the Army Community contributes its experiences with using remote sensing to manage and monitor its valued resources. We welcome corrections, additions, and suggestions.

4. How to use this guide

Step 1: Locate your broad management objective and ecoregion in the ***Selection Key***
Step 2: Locate your specific land management objective
Step 3: Make note of the sensors listed
Step 4: Remove applicable ***Sensor Fact Sheets*** from binder
Step 5: Do a side-by-side comparison of the sensors (costs, frequency of collection, etc.)
Step 6: Determine which sensor best meets your needs
Step 7: Use the ***Procurement Section*** for guidance on imagery acquisition

II. IMAGERY SELECTION KEYS

A. About the Keys

1. Ecoregion Organization:

Each imagery selection key is organized into five ecoregions for the conterminous United States. Ecoregions used in this report are "lumped" to reduce the confusion that may result from repeated references for applications in similar areas. The ecoregion combinations selected for inclusion in the key are based on adjacency and similarities between ecoregions, presence or absence of Army Installations, and other factors. The regions given the greatest attention were those with the highest concentration of Army Installations: Southeast, Southern Plains, Pacific Southwest, and Northwest United States.

Alaska and Hawaii are ecologically unique compared to the mainland United States. Installation natural resource managers in either state should contact either the USAEC's Conservation Assistance Program or TEC's Operations Directorate directly for assistance in determining the most appropriate imagery for their needs, locating imagery, or developing Statements of Work. Points-of-Contact are listed in the procurement section of this guide.

2. Applicable Sensors Based on Management Objective & Region:

Three sections of broad management objectives are included in the Selection Keys; Vegetation, Soils & Soil Erosion, and Land Management/Disturbance Detection. Each objective is organized by ecoregion. Within these sections, more specific objectives are listed from coarse to finer scale, with recommended sensor platforms for each level.

3. Imagery Selection Key Example:

Vegetation Key

Region (Southeast / Northeast)

a. coarser management objective(major cover type identification)

1. applicable sensors

b. finer management objective (single tree identification)

1. applicable sensors

Soils & Soil Erosion Key

Land Management / Disturbance Detection Key

Note: Corresponding Federal Geographic Data Committee Vegetation Subcommittee terms are in parentheses next to this report's categories.

B. Vegetation Key

1. Ecoregion: Southeast/Northeast

1. Major Cover Types (Physiognomic Group/Subgroup)

a. Definition: Separation of major vegetation types from other types (e.g., forest from agricultural from barren). Information that may be expected to be found at the level of an early earth-satellite image.

b. Applicable Sensors:

Landsat TM (Hodgson, et al., 1988) (Cook, et al., 1989) (Brockhaus, et al., 1993)
SPOT XS (Rutchey and Vilcheck, 1994)

2. Broad Vegetation Groups (Formation)

a. Definition: Recognition of broad vegetative types, such as herbaceous versus shrub meadows, deciduous versus evergreen forests, croplands versus orchards.

b. Applicable Sensors:

Landsat TM (Brannon, et al., 1996) (Schriever and Congalton, 1993)
SPOT XS (Muchoney and Haack, 1994)
SPOT PAN
Standard Aerial Photography (Cablk, et al., 1994)
Digital Aerial Orthophotography with Multispectral

3. Major Community Types (Alliance)

a. Definition: Direct identification of major community types and species occurring in pure stands, such as white pine versus cedar, mixed oak versus maple, and seasonal dominant grasses.

b. Applicable Sensors:

SPOT XS (Narumalani and Carbone, 1993)
SPOT PAN (Jensen, et al., 1991)
Standard Aerial Photography (Jensen, et al., 1986) (Jensen, et al., 1991)
Digital Aerial Orthophotography (Needham and Smith, 1987)
Digital Aerial Orthophotography with Multispectral

4. Single Trees/Large Shrubs (Community Association)

a. Definition: Identification of individual trees and large shrubs.

b. Applicable Sensors:

Standard Aerial Photography (Jacobs, et al., 1993)
Digital Multispectral Video
Digital Aerial Orthophotography

5. *Single Plants/Grassland Types (Community Association)*
   - a. **Definition:** Identification of individual plants and grassland types.
   - b. **Applicable Sensors:**
     - Digital Aerial Orthophotography
     - Digital Multispectral Video

6. *Seasonal Greenup*
   - a. **Definition:** Detection of increased reflectance caused by spring revegetation.
   - b. **Applicable Sensors:**
     - Landsat TM
     - SPOT XS
     - SPOT PAN
     - Standard Aerial Photography
     - Digital Multispectral Video

7. *Water Stress*
   - a. **Definition:** Detection of change in plant conditions caused by flooding, drought, effects of high temperatures.
   - b. **Applicable Sensors:**
     - Standard Aerial Photography (Welch, et al., 1988)
     - Digital Multispectral Video

8. *Other Plant Stress*
   - a. **Definition:** Detection of stress caused by disease, insect attack, fire, air pollution, seasonal senescence.
   - b. **Applicable Sensors:**
     - Landsat MSS (Muchoney and Haack, 1994) (Mukai, et al., 1987)
     - Landsat TM (Muchoney and Haack, 1994)
     - SPOT XS (Muchoney and Haack, 1994) (Ciesla, et al., 1989)
     - Standard Aerial Photography (Ciesla, et al., 1989)
     - Digital Aerial Orthophotography (Murtha and Wiart, 1989)
     - Digital Multispectral Video

9. *Large Floodplains/Wetlands, Playas*
   - a. **Definition:** Detection of floodplains for streams of stream order 3 or higher; delineation of wetlands of five acres or larger.
   - b. **Applicable Sensors:**
     - Landsat MSS
     - Landsat TM (Tao, 93)
     - SPOT XS (Rutchey and Vilcheck, 1994)
     - SPOT Panchromatic (Jensen, et al., 1993)

Standard Aerial Photography (Tiner and Smith, 1992) (Jacobs et al., 1993)

10. Stream Floodplain/Small Marshes, Swamps

a. Definition: Detection of headwater (stream order 2 or lower) floodplains; meander floodplain detection (characterized by features such as channel scars, oxbow lakes, meander scrolls); identifying riverine floodplains.

b. Applicable Sensors:

Standard Aerial Photography (Jensen, et al., 1993)
(Mackey, 1993) (Rizzo, et al., 1996)
Digital Multispectral Video
Digital Aerial Orthophotography

C. Vegetation Key

1. Ecoregion: Southern Plains/Southwest/Pacific Southwest

1. Major Cover Types (Physiognomic Group/Subgroup)

a. Definition: Separation of major vegetation types from other types (e.g., grassland from agricultural from barren). Information that may be expected to be found at the level of an early earth-satellite image.

b. Applicable Sensors:

Landsat MSS (Pickup, et al., 1993) (Satterwhite, 1984)
(Chavez, 1994)

Landsat TM (Franklin, et al., 1991)
(Stenback and Congalton, 1990)
(Collins and Woodcock, 1996)
(Smith, et al., 1990)
(Satterwhite, 1984)

SPOT XS

2. Broad Vegetation Groups (Formation)

a. Definition: Recognition of broad vegetative types, such as herbaceous versus shrub rangelands, deciduous versus evergreen forests, croplands versus rangelands.

b. Applicable Sensors:

SPOT XS
SPOT PAN
Standard Aerial Photography (Baker, 1989)
Digital Aerial Orthophotography with Multispectral

3. Major Community Types (Alliance)

a. Definition: Direct identification of major community types and species occurring in pure stands, such as Grama Grass versus Mesquite, Oak/Juniper versus Pine, and seasonal dominant grasses.

b. Applicable Sensors:

SPOT XS
SPOT PAN
Standard Aerial Photography
Digital Aerial Orthophotography with Multispectral

4. Single Trees/Large Shrubs (Community Association)

a. Definition: Identification of individual trees and large shrubs.

b. Applicable Sensors:

Standard Aerial Photography
Digital Multispectral Video

5. *Single Plants/Grassland Types (Community Association)*

a. Definition: Identification of individual plants and grassland types.

b. Applicable Sensors:

Digital Aerial Orthophotography
Digital Multispectral Video

6. *Seasonal Greenup*

a. Definition: Ability to detect increased reflectance caused by spring revegetation.

b. Applicable Sensors:

Landsat TM
SPOT XS
SPOT PAN
Standard Aerial Photography
Digital Multispectral Video

7. *Water Stress*

a. Definition: Detection of change in plant conditions caused by flooding, drought, and high temperatures.

b. Applicable Sensors:

Standard Aerial Photography
Digital Multispectral Video

8. *Other Plant Stress*

a. Definition: Detection of stress caused by disease, insect attack, fire, air pollution, seasonal senescence.

b. Applicable Sensors:

Landsat MSS
Landsat TM
SPOT XS
Standard Aerial Photography
Digital Aerial Orthophotography
Digital Multispectral Video

9. *Large floodplains/wetlands, playas*

a. Definition: Detection of floodplains for streams of stream order 3 or higher; delineation of wetlands/playas of five acres or larger.

b. Applicable Sensors:

Landsat MSS
Landsat TM
SPOT XS
Standard Aerial Photography

10. Stream floodplain/small marshes, swamps

a. Definition: Detection of headwater (stream order 2 or lower) floodplains; meander floodplain detection (characterized by features such as channel scars, oxbow lakes, meander scrolls); identifying riverine floodplains.

b. Applicable Sensors:

Standard Aerial Photography
Digital Multispectral Video
Digital Aerial Orthophotography

D. Vegetation Key

1. Ecoregion: Pacific Northwest

1. Major Cover Types (Physiognomic Group/Subgroup)

a. Definition: Separation of major vegetation types from other types (e.g., forest from agricultural from barren). Information that may be expected to be found at the level of an early earth-satellite image.

b. Applicable Sensors:

Landsat MSS (Talbot and Markon, 1988)
(Felix and Binney, 1989)
Landsat TM (Fiorella and Ripple, 1993)
SPOT XS

2. Broad Vegetation Groups (Formation)

a. Definition: Recognition of broad vegetative types, such as deciduous versus evergreen forests, croplands versus orchards.

b. Applicable Sensors:

SPOT XS
SPOT PAN
Standard Aerial Photography (Winterberger and Larson, 1988)
Digital Aerial Orthophotography with Multispectral

3. Major Community Types (Alliance)

a. Definition: Direct identification of major community types and species occurring in pure stands, such as Douglas Fir versus Cedar, Hemlock versus Silver Fir, and seasonal dominant grasses.

b. Applicable Sensors:

SPOT XS
SPOT PAN
Standard Aerial Photography (Paine and McCadden, 1988)
Digital Aerial Orthophotography with Multispectral

4. Single Trees/Large Shrubs (Community Association)

a. Definition: Identification of individual trees and large shrubs.

b. Applicable Sensors:

Standard Aerial Photography (Paine and McCadden, 1988)
Digital Multispectral Video
Digital Aerial Orthophotography

5. Single Plants/Grassland Types (Community Association)

a. Definition: Identification of individual plants and grassland types.

b. Applicable Sensors:

Digital Aerial Orthophotography
Digital Multispectral Video

6. *Seasonal Greenup*

a. Definition: Ability to detect increased reflectance caused by spring revegetation.

b. Applicable Sensors:

Landsat TM
SPOT XS
SPOT PAN
Standard Aerial Photography
Digital Multispectral Video

7. *Water Stress*

a. Definition: Detection of change in plant conditions caused by flooding, drought, effects of high temperatures.

b. Applicable Sensors:

Standard Aerial Photography
Digital Multispectral Video

8. *Other Plant Stress*

a. Definition: Detection of stress caused by disease, insect attack, fire, air pollution, seasonal senescence.

b. Applicable Sensors:

Landsat MSS
Landsat TM
SPOT XS
Standard Aerial Photography
Digital Aerial Orthophotography
Digital Multispectral Video

9. *Large floodplains/wetlands, playas*

a. Definition: Detection of floodplains for streams of stream order 3 or higher; delineation of wetlands of five acres or larger.

b. Applicable Sensors:

Landsat MSS
Landsat TM
SPOT XS
Standard Aerial Photography

10. Stream floodplain/small marshes, swamps

a. Definition: Detection of headwater (stream order 2 or lower) floodplains; meander floodplain detection (characterized by features such as channel scars, oxbow lakes, meander scrolls); identifying riverine floodplains.

b. Applicable Sensors:

Standard Aerial Photography
Digital Multispectral Video
Digital Aerial Orthophotography

E. Vegetation Key

1. Ecoregion: Northern Plains/North Central

1. Major Cover Types (Physiognomic Group/Subgroup)

a. Definition: Separation of major vegetation types from other types (e.g., forest from agricultural from barren). Information that may be expected to be found at the level of an early earth-satellite image.

b. Applicable Sensors:

Landsat MSS (Karteris, 1988)
Landsat TM (Ormsby and Lunetta, 1987) (Warner et al., 1991) (Johnston and Bonde, 1989) (Cook, et al., 1989) (Chavez and Kwarteng, 1989) (Anderson, et al., 1993)
SPOT XS

2. Broad Vegetation Groups (Formation)

a. Definition: Recognition of broad vegetative types, such as prairies versus groves versus deciduous strips, croplands versus orchards.

b. Applicable Sensors:

Landsat TM (Lauver and Whistler, 1993) (Johnston and Bonde, 1989) (Heilman and Boyd, 1986) (Herr and Queen, 1993)
SPOT XS (Briggs and Nellis, 1991)
SPOT PAN
Standard Aerial Photography
Digital Aerial Orthophotography with Multispectral

3. Major Community Types (Alliance)

a. Definition: Direct identification of major community types and species occurring in pure stands, such as cottonwood versus Black Willow and seasonal dominant grasses.

b. Applicable Sensors:

SPOT XS
SPOT PAN
Standard Aerial Photography (Frank and Isard, 1986)
Digital Aerial Orthophotography with Multispectral

4. Single Trees/Large Shrubs (Community Association)

a. Definition: Identification of individual trees and large shrubs.

b. Applicable Sensors:

Standard Aerial Photography
Digital Multispectral Video

Digital Aerial Orthophotography

5. *Single Plants/Grassland Types (Community Association)*

   a. Definition: Identification of individual plants and grassland types.

   b. Applicable Sensors:

   Standard Aerial Photography (Chapman, et al., 1993)
   Digital Aerial Orthophotography
   Digital Multispectral Video

6. *Seasonal Greenup*

   a. Definition: Ability to detect increased reflectance caused by spring revegetation.

   b. Applicable Sensors:

   Landsat TM
   SPOT XS
   Standard Aerial Photography
   Digital Multispectral Video

7. *Water Stress*

   a. Definition: Detection of change in plant conditions caused by flooding, drought, effects of high temperatures.

   b. Applicable Sensors:

   Standard Aerial Photography
   Digital Multispectral Video

8. *Other Plant Stress*

   a. Definition: Detection of stress caused by disease, insect attack, fire, air pollution, seasonal senescence.

   b. Applicable Sensors:

   Landsat MSS
   Landsat TM (Joria, et al., 1991)
   SPOT XS (Joria, et al., 1991)
   Standard Aerial Photography
   Digital Aerial Orthophotography
   Digital Multispectral Video

9. *Large floodplains/wetlands, playas*

   a. Definition: Detection of floodplains for streams of stream order 3 or higher; delineation of wetlands/playas of five acres or larger.

   b. Applicable Sensors:

   Landsat MSS
   Landsat TM
   SPOT XS
   Standard Aerial Photography (Carter, et al., 1979)

RADARSAT Radar (Paterson, et al., 1996)
Digital Aerial Orthophotography (Lyon, and Greene, 1992)

10. Stream floodplain/small marshes, swamps

a. Definition: Detection of headwater (stream order 2 or lower) floodplains; meander floodplain detection (characterized by features such as channel scars, oxbow lakes, meander scrolls); identifying riverine floodplains.

b. Applicable Sensors:

Standard Aerial Photography
Digital Multispectral Video
Digital Aerial Orthophotography

F. Vegetation Key

1. Ecoregion: Great Basin/Rocky Mountains

1. Major Cover Types (Physiognomic Group/Subgroup)

a. Definition: Separation of major vegetation types from other types (e.g., forest from agricultural from barren). Information that may be expected to be found at the level of an early earth-satellite image.

b. Applicable Sensors:

Landsat MSS (Price, et al., 1992)
Landsat TM (Frank, 1988) (Chavez and Kwarteng, 1989)
(Stenback and Congalton, 1990)
(Collins and Woodcock, 1996)
(Walsh, 1993) (Evans and Smith, 1991)
SPOT XS (Walsh, 1993)

2. Broad Vegetation Groups (Formation)

a. Definition: Recognition of broad vegetative types, such as herbaceous versus shrub meadows, deciduous versus evergreen forests, croplands versus orchards.

b. Applicable Sensors:

Landsat TM (Frank, 1988) (Franklin, 1994)
(Price, et al., 1992) (Hewitt, 1990)
SPOT XS
SPOT PAN
Standard Aerial Photography (Befort, 1986)
(Tueller, et al., 1988)
Digital Aerial Orthophotography with Multispectral

3. Major Community Types (Alliance)

a. Definition: Direct identification of major community types and species occurring in pure stands, such as Ponderosa Pine versus fir, sagebrush versus grass, and seasonal dominant grasses.

b. Applicable Sensors:

SPOT XS
SPOT PAN
Standard Aerial Photography (Frank and Isard, 1986)
(Paine and McCadden, 1988) (Meyer, et al., 1996)
Digital Aerial Orthophotography with Multispectral

4. Single Trees/Large Shrubs (Community Association)

a. Definition: Identification of individual trees and large shrubs.

b. Applicable Sensors:

Standard Aerial Photography (Paine and McCadden, 1988)

Digital Multispectral Video

5. *Single Plants/Grassland Types (Community Association)*
   a. **Definition:** Identification of individual plants and grassland types.
   b. **Applicable Sensors:**
      Digital Aerial Orthophotography
      Digital Multispectral Video

6. *Seasonal Greenup*
   a. **Definition:** Ability to detect increased reflectance caused by spring revegetation.
   b. **Applicable Sensors:**
      Landsat TM
      SPOT XS
      SPOT PAN
      Standard Aerial Photography
      Digital Multispectral Video

7. *Water Stress*
   a. **Definition:** Detection of change in plant conditions caused by flooding, drought, effects of high temperatures.
   b. **Applicable Sensors:**
      Standard Aerial Photography
      Digital Multispectral Video

8. *Other Plant Stress*
   a. **Definition:** Detection of stress caused by disease, insect attack, fire, air pollution, seasonal senescence.
   b. **Applicable Sensors:**
      Landsat MSS
      Landsat TM
      SPOT XS
      Standard Aerial Photography
      Digital Aerial Photography
      Digital Multispectral Video

9. *Large floodplains/wetlands, playas*
   a. **Definition:** Detection of floodplains for streams of stream order 3 or higher; delineation of wetlands of five acres or larger.
   b. **Applicable Sensors:**
      Landsat MSS
      Landsat TM
      SPOT XS
      Standard Aerial Photography

10. Stream floodplain/small marshes, swamps

a. Definition: Detection of headwater (stream order 2 or lower) floodplains; meander floodplain detection (characterized by features such as channel scars, oxbow lakes, meander scrolls); identifying riverine floodplains.

b. Applicable Sensors:

Standard Aerial Photography
Digital Multispectral Video
Digital Aerial Orthophotography

G. *Soils and Erosion Key*

Soils types are often inferred from the vegetation types that have adapted to specific soils. Level of detail in soil mapping may be limited by the ability to map vegetation on those soils. Elevation differences, which can be derived from stereo photographs or obtained directly from digital elevation models, can be useful in separating landscape features and major soil types.

1. Ecoregion: Southeast/Northeast

1. Landscapes/Large Soil Units

a. Definition:

Capability to identify major soil units or landscape elements indirectly using drainages, topography and vegetation; delineating land and rural areas; identification of objects at scales ranging from 1:100,000 to 1:8,000.

b. Applicable Sensors:

Landsat MSS
Landsat TM
SPOT PAN (Bolstad and Stowe, 1994)
SPOT XS

2. Detailed Base-scale Soil Maps

a. Definition:

Analogous to Natural Resource Conservation System soil maps at scales ranging from 1:6000 or larger. Detects small landscape patterns that control soil development, such as microtopography (drainages, slopes, etc.).

b. Applicable Sensors:

Standard Aerial Photography
Digital Aerial Orthophotography
Digital Multispectral Video

3. Individual Erosion Sites

a. Definition:

Identification of gully and rill erosion almost at the inception of such erosion.

b. Applicable Sensors:

SPOT PAN
Standard Aerial Photography
Digital Multispectral Video
IFSAR Radar

4. Sedimentation in Receiving Water Bodies

a. Definition: Delineating coastal shorelines; determining water current direction as indicated by color differences (i.e., tributary entering larger water feature, chlorophyll or sediment patterns).

b. Applicable Sensors:

Landsat MSS (Ritchie et al., 1990)
Landsat TM (Ritchie et al., 1990)
SPOT XS
SPOT PAN
Standard Aerial Photography
Digital Aerial Orthophotography
Digital Multispectral Video

5. *Soil Moisture*

a. Definition: Detection of saturated or flooded soil.

b. Applicable Sensors:

Standard Aerial Photography
SPOT XS
SPOT PAN
IFSAR and RADARSAT Radar

6. ***Flooding***

a. Definition: Detection of overbank and overdune flooding in lake and river floodplain or coastal overwash areas.

b. Applicable Sensors:

SPOT XS (Houhoulis and Michener, 1996)
SPOT PAN
Standard Aerial Photography
IFSAR and RADARSAT Radar
Digital Aerial Orthophotography
Digital Multispectral Video

H. Soils and Erosion Key

Soils types are often inferred from the vegetation types that have adapted to specific soils. Level of detail in soil mapping may be limited by the ability to map vegetation on those soils. Elevation differences, which can be derived from stereo photographs or obtained directly from digital elevation models, can be useful in separating landscape features and major soil types.

1. Ecoregion: Southern Plains/Southwest/Pacific Southwest

1. Landscapes/Large Soil Units

a. Definition:

Capability to identify major soil units or landscape elements indirectly using drainages, topography and vegetation; delineating land and rural areas; identification of objects at scales ranging from 1:100,000 to 1:8,000.

b. Applicable Sensors:

Landsat MSS
Landsat TM (Paisley, et al., 1991)
SPOT PAN
SPOT XS
IFSAR Radar (Zebker, et al., 1994)

2. Detailed Base-scale Soil Maps

a. Definition:

Analogous to Natural Resource Conservation System soil maps at scales ranging from 1:6000 or larger. Detects small landscape patterns that control soil development, such as microtopography (drainages, slopes, etc.).

b. Applicable Sensors:

Standard Aerial Photography
Digital Aerial Orthophotography
Digital Multispectral Video

3. Individual Erosion Sites

a. Definition:

Identification of gully and rill erosion almost at the inception of such erosion.

b. Applicable Sensors:

SPOT PAN
Standard Aerial Photography
Digital Aerial Orthophotography (Lyon et al., 1986)
Digital Multispectral Video
IFSAR Radar

4. Sedimentation in Receiving Water Bodies

a. **Definition:** Delineating coastal shorelines; determining water current direction as indicated by color differences (i.e., tributary entering larger water feature, chlorophyll or sediment patterns).

b. **Applicable Sensors:**

Landsat MSS
Landsat TM
SPOT XS
SPOT PAN
Standard Aerial Photography
Digital Aerial Orthophotography
Digital Multispectral Video

5. *Soil Moisture*

a. **Definition:** Detection of saturated or flooded soil.

b. **Applicable Sensors:**

Standard Aerial Photography
SPOT XS
SPOT PAN
IFSAR and RADARSAT Radar

6. *Flooding*

a. **Definition:** Detection of overbank and overdune flooding in lake and river floodplain or coastal overwash areas.

b. **Applicable Sensors:**

SPOT XS
SPOT PAN
Standard Aerial Photography
IFSAR and RADARSAT Radar
Digital Aerial Orthophotography
Digital Multispectral Video

I. Soils and Erosion Key

Soils types are often inferred from the vegetation types that have adapted to specific soils. Level of detail in soil mapping may be limited by the ability to map vegetation on those soils. Elevation differences, which can be derived from stereo photographs or obtained directly from digital elevation models, can be useful in separating landscape features and major soil types.

1. Ecoregion: Pacific Northwest

1. Landscapes/Large Soil Units

a. Definition:
Capability to identify major soil units or landscape elements indirectly using drainages, topography and vegetation; delineating land and rural areas; identification of objects at scales ranging from 1:100,000 to 1:8,000.

b. Applicable Sensors:
- Landsat MSS
- Landsat TM
- SPOT PAN
- SPOT XS

2. Detailed Base-scale Soil Maps

a. Definition:
Analogous to Natural Resource Conservation System soil maps at scales ranging from 1:6000 or larger. Detects small landscape patterns that control soil development, such as microtopography (drainages, slopes, etc.).

b. Applicable Sensors:
- Standard Aerial Photography
- Digital Aerial Orthophotography
- Digital Multispectral Video

3. Individual Erosion Sites

a. Definition:
Identification of gully and rill erosion almost at the inception of such erosion.

b. Applicable Sensors:
- SPOT PAN
- Standard Aerial Photography
- Digital Multispectral Video
- IFSAR Radar

4. Sedimentation in Receiving Water Bodies

a. Definition: Delineating coastal shorelines; determining water current direction as indicated by color differences (i.e., tributary entering larger water feature, chlorophyll or sediment patterns).

b. Applicable Sensors:

Landsat MSS
Landsat TM
SPOT XS
SPOT PAN
Standard Aerial Photography
Digital Aerial Orthophotography
Digital Multispectral Video

5. Soil Moisture

a. Definition: Detection of saturated or flooded soil.

b. Applicable Sensors:

Standard Aerial Photography
SPOT XS
SPOT PAN
IFSAR and RADARSAT Radar

6. Flooding

a. Definition: Detection of overbank and overdune flooding in lake and river floodplain or coastal overwash areas.

b. Applicable Sensors:

SPOT XS
SPOT PAN
Standard Aerial Photography
IFSAR and RADARSAT Radar
Digital Aerial Orthophotography
Digital Multispectral Video

J. Soils and Erosion Key

Soils types are often inferred from the vegetation types that have adapted to specific soils. Level of detail in soil mapping may be limited by the ability to map vegetation.on those soils. Elevation differences, which can be derived from stereo photographs or obtained directly from digital elevation models, can be useful in separating landscape features and major soil types.

1. Ecoregion: Northern Plains/North Central

1. Landscapes/Large Soil Units

a. Definition:

Capability to identify major soil units or landscape elements indirectly using drainages, topography and vegetation; delineating land and rural areas; identification of objects at scales ranging from 1:100,000 to 1:8,000.

b. Applicable Sensors:

Landsat MSS
Landsat TM
SPOT PAN
SPOT XS (Agbu and Nizeyimana, 1991) (Senseman, et al.,1994)

2. Detailed Base-scale Soil Maps

a. Definition:

Analogous to Natural Resource Conservation System soil maps at scales ranging from 1:6000 or larger. Detects small landscape patterns that control soil development, such as microtopography (drainages, slopes, etc.).

b. Applicable Sensors:

Standard Aerial Photography
Digital Aerial Orthophotography
Digital Multispectral Video

3. Individual Erosion Sites

a. Definition:

Identification of gully and rill erosion almost at the inception of such erosion.

b. Applicable Sensors:

SPOT PAN
Standard Aerial Photography
Digital Multispectral Video
IFSAR Radar

4. Sedimentation in Receiving Water Bodies

a. Definition: Delineating coastal shorelines; determining water current direction as indicated by color differences (i.e., tributary entering larger water feature, chlorophyll or sediment patterns).

b. Applicable Sensors:

Landsat MSS
Landsat TM (Lathrop, 1992)
SPOT XS (Lathrop and Lillesand, 1989)
SPOT PAN
Standard Aerial Photography
Digital Aerial Orthophotography
Digital Multispectral Video

5. *Soil Moisture*

a. Definition: Detection of saturated or flooded soil.

b. Applicable Sensors:

Standard Aerial Photography
SPOT XS
SPOT PAN
IFSAR and RADARSAT Radar

6. *Flooding*

a. Definition: Detection of overbank and overdune flooding in lake and river floodplain or coastal overwash areas.

b. Applicable Sensors:

SPOT XS
SPOT PAN
Landsat TM (Hough, 1994)
Standard Aerial Photography
IFSAR and RADARSAT Radar
Digital Aerial Orthophotography
Digital Multispectral Video

K. Soils and Erosion Key

Soils types are often inferred from the vegetation types that have adapted to specific soils. Level of detail in soil mapping may be limited by the ability to map vegetation on those soils. Elevation differences, which can be derived from stereo photographs or obtained directly from digital elevation models, can be useful in separating landscape features and major soil types.

1. Ecoregion: Great Basin/Rocky Mountains

1. Landscapes/Large Soil Units

a. Definition:

Capability to identify major soil units or landscape elements indirectly using drainages, topography and vegetation; delineating land and rural areas; identification of objects at scales ranging from 1:100,000 to 1:8,000.

b. Applicable Sensors:

Landsat MSS
Landsat TM (Frazier and Cheng, 1989)
SPOT PAN
SPOT XS
IFSAR Radar (Zebker, et al., 1994)

2. Detailed Base-scale Soil Maps

a. Definition:

Analogous to Natural Resource Conservation System soil maps at scales ranging from 1:6000 or larger. Detects small landscape patterns that control soil development, such as microtopography (drainages, slopes, etc.).

b. Applicable Sensors:

Standard Aerial Photography
Digital Aerial Orthophotography
Digital Multispectral Video

3. Individual Erosion Sites

a. Definition:

Identification of gully and rill erosion almost at the inception of such erosion.

b. Applicable Sensors:

SPOT PAN
Standard Aerial Photography
Digital Multispectral Video
IFSAR Radar

4. Sedimentation in Receiving Water Bodies

a. **Definition:** Delineating coastal shorelines; determining water current direction as indicated by color differences (i.e., tributary entering larger water feature, chlorophyll or sediment patterns).

b. **Applicable Sensors:**

Landsat MSS
Landsat TM (Lathrop, 1992)
SPOT XS
SPOT PAN
Standard Aerial Photography
Digital Aerial Orthophotography
Digital Multispectral Video

5. ***Soil Moisture***

a. **Definition:** Detection of saturated or flooded soil.

b. **Applicable Sensors:**

Standard Aerial Photography
SPOT XS and PAN
IFSAR and RADARSAT Radar

6. ***Flooding***

a. **Definition:** Detection of overbank and overdune flooding in lake and river floodplain or coastal overwash areas.

b. **Applicable Sensors:**

SPOT XS
SPOT PAN
Standard Aerial Photography
IFSAR and RADARSAT Radar
Digital Aerial Orthophotography
Digital Multispectral Video

L. *Land Management / Disturbance Detection Key*

1. Ecoregion: Southeast/Northeast

1. To Examine Management Effects

a. Definition: Detection of large-scale prescribed burns, wildfire, chemical or physical vegetation removal, conservation or forage mowing/seeding, habitat identification, habitat suitability, land use management, water quality.

b. Applicable Sensors:

Landsat TM (Hodgson, et al., 1987) (Hodgson, et al., 1988)
SPOT XS
SPOT PAN
Digital Aerial Orthophotography
Standard Aerial Photography (Welch, et al., 1988)
(Breininger, et al., 1991)

2. To Examine Disturbance/Horticulture Effects

a. Definition: Maneuver damage, bivouac effects, training effects, firing range fires, natural or seeded/planted revegetation progress, conservation plantings.

b. Applicable Sensors:

Landsat TM
SPOT XS
SPOT PAN
Standard Aerial Photography
Digital Aerial Orthophotography
Digital Multispectral Video

M. Land Management / Disturbance Detection Key

1. Ecoregion: Southern Plains/Southwest/Pacific Southwest

1. To Examine Management Effects

a. Definition: Detection of large-scale prescribed burns, wildfire, chemical or physical vegetation removal, conservation or forage mowing/seeding, habitat identification, habitat suitability, land use management.

b. Applicable Sensors:

Landsat TM
SPOT XS
SPOT PAN
Digital Aerial Orthophotography
Standard Aerial Photography (Chou, et al., 1990)

2. To Examine Disturbance/Horticulture Effects

a. Definition: Maneuver damage, bivouac effects, training effects, firing range fires, natural or seeded/planted revegetation progress, conservation plantings.

b. Applicable Sensors:

Landsat MSS (Pilon, et al., 1988)
Landsat TM
SPOT XS
SPOT PAN
Standard Aerial Photography
Digital Aerial Orthophotography
Digital Multispectral Video

N. Land Management / Disturbance Detection Key

1. Ecoregion: Pacific Northwest

1. To Examine Management Effects

a. Definition: Detection of large-scale prescribed burns, wildfire, chemical or physical vegetation removal, conservation or forage mowing/seeding, habitat identification, habitat suitability, land use management.

b. Applicable Sensors:

Landsat TM
SPOT XS
SPOT PAN
Digital Aerial Orthophotography

2. To Examine Disturbance/Horticulture Effects

a. Definition: Maneuver damage, bivouac effects, training effects, firing range fires, natural or seeded/planted revegetation progress, conservation plantings.

b. Applicable Sensors:

Landsat TM
SPOT XS
SPOT PAN
Standard Aerial Photography
Digital Aerial Orthophotography
Digital Multispectral Video

O. Land Management / Disturbance Detection Key

1. Ecoregion: Northern Plains/North Central

1. To Examine Management Effects

a. Definition: Detection of large-scale prescribed burns, wildfire, chemical or physical vegetation removal, conservation or forage mowing/seeding, habitat identification, habitat suitability, land use management, water quality.

b. Applicable Sensors:

Landsat TM (Ormsby and Lunetta, 1987) (Roseberry, et al.,1994) (Lathrop, 1992) (Jakubauskas, et al., 1990) (Herr and Queen, 1993)
SPOT XS (Senseman, et al., 1994)
SPOT PAN
Digital Aerial Orthophotography

2. To Examine Disturbance/Horticulture Effects

a. Definition: Maneuver damage, bivouac effects, training effects, firing range fires, natural or seeded/planted revegetation progress, conservation plantings.

b. Applicable Sensors:

Landsat TM
SPOT XS
SPOT PAN
Standard Aerial Photography
Digital Aerial Orthophotography
Digital Multispectral Video

P. Land Management / Disturbance Detection Key

1. Ecoregion: Great Basin/Rocky Mountains

1. To Examine Management Effects

a. Definition: Detection of large-scale prescribed burns, wildfire, chemical or physical vegetation removal, conservation or forage mowing/seeding, habitat identification, habitat suitability, land use management, water quality.

b. Applicable Sensors:

Landsat TM (Lathrop, 1992) (Lathrop, et al., 1994)
SPOT XS (Verbyla, et al., 1993)
SPOT PAN
Digital Aerial Orthophotography

2. To Examine Disturbance/Horticulture Effects

a. Definition: Maneuver damage, bivouac effects, training effects, firing range fires, natural or seeded/planted revegetation progress, conservation plantings.

b. Applicable Sensors:

Landsat TM
SPOT XS
SPOT PAN
Standard Aerial Photography
Digital Aerial Orthophotography
Digital Multispectral Video

III. BASIC SENSOR INFORMATION

A. Sensor Matrix

SENSOR	Spatial Resolution	Revisit Time	Operational Dates	Wavelength Regions	# of Bands	Fact Sheet #	Order Time	Cost	Utility
Landsat MSS	80 meter	16-18 days	since 1972	0.50-1.1 um	4	1	Fast	Low	Low
Landsat TM	30 meter	16 days	since 3/84	0.45-2.35 um	6	2	Fast	Low	Med
	120 meter	16 days	since 3/84	10.4-12.4 um	1	2	Fast	Low	Med
SPOT PAN	10 meter	26 days	since 2/86	0.51-0.73 um	1	3	Fast	Med	High
SPOT XS	30 meter	26 days	since 2/86	0.50-0.89 um	3	3	Fast	Med	High
Standard Aerial Photo	variable	user-defined	since 1980	B&W, Color IR		4	Med	Low	High
				Color		4	Med	Low	High
Radar (RADARSAT)	10-30 meter	2-9 days	since 10/95	C-Band SAR		5	Fast	Med	Med
Radar (IFSAR)	5-10 meter elevations	user-defined	since 1995			5	Med	High	High
Digital Aerial Orthophotography	variable	user-defined	since 1980s	user-defined		6	Slow	High	High
Digital Multispectral Imagery	0.25 meter potential	user-defined	since 1994	0.35-0.95 um	4	7	Slow	High	High
<u>Pre-production:</u> **EarthWatch, Inc.**		2-3 times/day				8	Fast	N/A	High
EarlyBird-Pan	3 meter		launch in 1997	0.45-0.80 um	1				
EarlyBird-Multicolor	15 meter		launch in 1997	0.50-0.89 um	3				
QuickBird-Pan	1 meter		launch late 1997	0.45-0.90 um	1				
QuickBird-Multicolor	4 meter		launch late 1997	0.45-0.90 um	4				
<u>Pre-production:</u> **Space Imaging, Inc.**		2-4 days	launch 1997			9	Fast	N/A	High
Panchromatic	1 meter			0.45-0.90 um	1				
Multispectral	4 meters			0.45-0.90 um	4				

Landsat MSS - Fact Sheet #1

Image 1. Landsat MSS image portrayed using 4-5-7 False-Color Composite depicts cinder cones, mountains, drainage, snow, and cultural features over North Central New Mexico.

Landsat TM - Fact Sheet #2

Image 2. Landsat TM imagery acquired over Joshua Tree National Park and Palm Springs, CA using 3-2-1 True-Color Band Comination.

Landsat TM - Fact Sheet #2

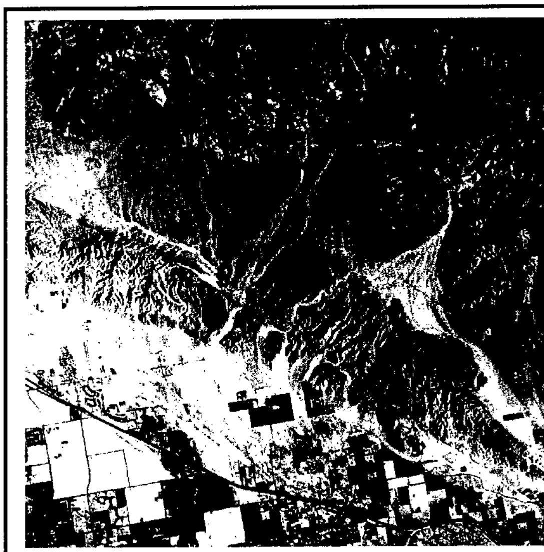

Image 3. Landsat TM imagery acquired over Joshua Tree National Park and Palm Springs, CA using 4-2-1False-Color Band Comination that emphasizes vegetation communities.

SPOT PAN - Fact Sheet #3

Image 4. SPOT Panchromatic image acquired over Ft. Irwin, CA. Panchromatic imagery is primarily intended for applications requiring fine geometric detail.

SPOT XS - Fact Sheet #3

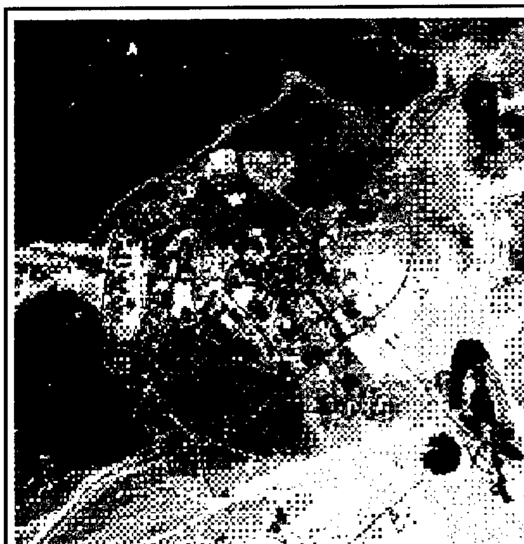

Image 5. SPOT XS (multispectral) image acquired over Ft. Irwin, CA The infrared spectra emphasize the vegetation communities.

Standard Aerial Photograph - Fact Sheet #4

Image 6. A 1954 black & white photograph over Fairfax County, VA. Historical photography is useful for monitoring changes.

Standard Aerial Photograph - Fact Sheet #4

Image 7. A color infrared photograph over a portion of Huntley Meadows Park in Fairfax County ,VA

Radarsat - Fact Sheet # 5

Image 8. Radarsat image of clear-cut forests over Okanagan, Canada.

IFSARE - Fact Sheet # 5

Image 9. IFSARE image over Sarajevo, Bosnia using color layers to depict elevation changes.

Digital Aerial Orthophotography - Fact Sheet #6

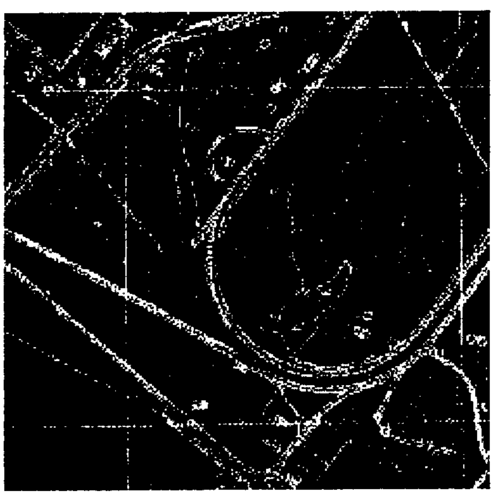

Image 10. Digital Aerial Orthophotography over Aberdeen Proving Ground. Very-large-scale photography enabled installation personnel to map vegetation, drainage, trails, and various cultural features on the installation. The imagery in the project can be used by all agencies at the base. More than 48,000 acres were mapped.

Digital Aerial Orthophotography - Fact Sheet #6

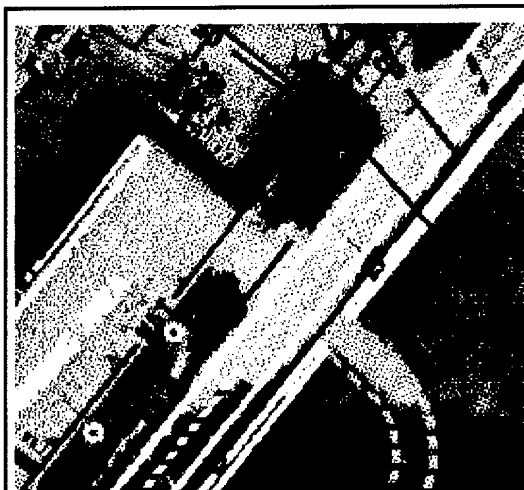

Image 11. Digital Aerial Orthophotography over Ft. Eustis, VA. Color-infrared and natural-color aerial photography were merged to delineate wetlands and other environmentally sensitive areas at Ft. Carson, CO. The work was part of a installation-wide Geographic Information Systems project.

Digital Multispectral Video - Fact Sheet #7

Image 12. Digital Multispectral Video image compiled using bands 0.75, 0.65, and 0.55 *um*. This combination shows the shoreline vegetation as well as the presence or absence of aquatic vegetation.

Digital Multispectral Video - Fact Sheet #7

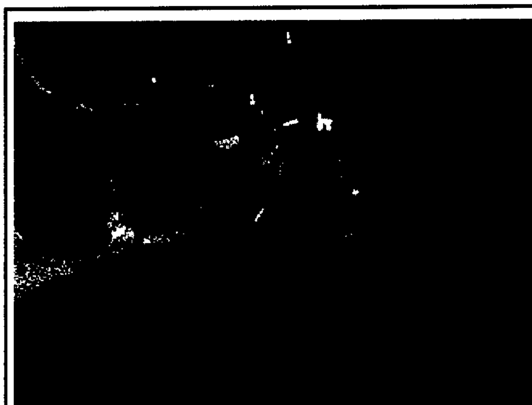

Image 13. DMSV image using a different combination of bands. Changing the band combinations to 0.77, 0.75, and 0.55 *um* shows density of aquatic vegetation.

EarthWatch - Fact Sheet #8

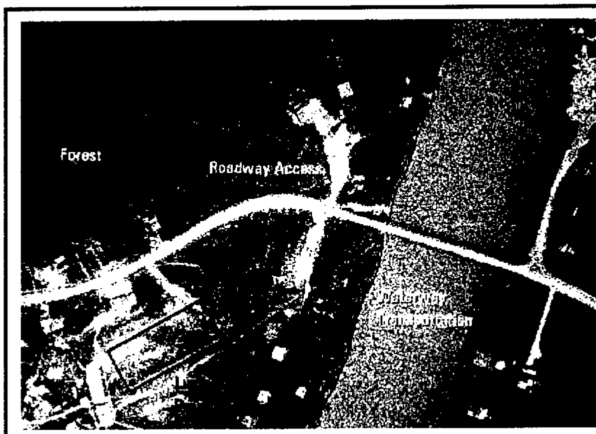

Image 14. This EarthWatch image depicts natural and cultural resource information required to locate a suitable lumber processing site.

Space Imaging - Fact Sheet #9

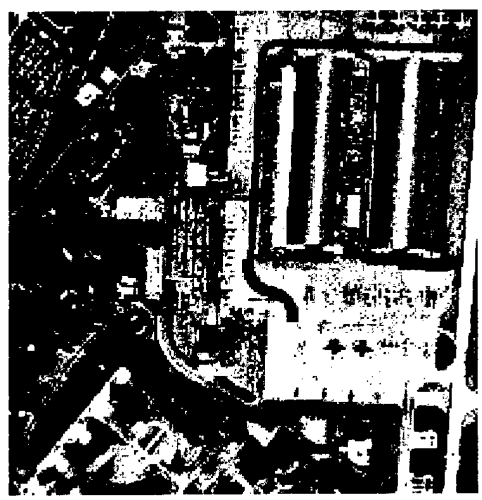

Image 15. This Space Imaging pan-sharpened image depicts multispectral data at 1-meter spacing. This image was collected over Moffett Naval Air Station.

LANDSAT MSS

Image 1. Landsat MSS image portrayed using 4-5-7 False-Color Composite depicts cinder cones, mountains, drainage, snow, and cultural features over North Central New Mexico.

Sensor Specifications

Spatial Resolution: 80-meter-square-pixels
Swath Width: 185 km
Revisit Time: 16 -18 days
Operational Dates: since 1972

Wavelength Regions

0.50 to 0.60 *um* [green]	0.70 to 0.80 *um* [NIR]
0.60 to 0.70 *um* [red]	0.80 to 1.10 *um*

General Discussion

The system can provide users with coarse scale imagery that covers large areas at relatively low cost. The costs could be minimal (i.e. $0 - $600) depending on the date of the imagery and if the imagery has been previously procured by another DoD agency.

Vendor Information

For more detailed information contact:

EOSAT's Customer Services Department
(301) 552-0537 or 1-800-344-9933 x537
email: custservices@eosat.com
web: http://www.eosat.com

or

EROS Data Center, USGS
User Services Section
Sioux Falls, SD 57198
Phone: (605) 594-6151 fax x6589
email: custserv@edcserver1.cr.usgs.gov
web: http://edcwww.cr.usgs.gov/webglis

U.S. Army Civil Imagery Acquisition Program

For availability questions and purchasing contact:
Topographic Engineering Center - Ops Directorate
7701 Telegraph Road
Alexandria, VA 22315-3864
Phone: (703) 428-6909 DSN 328-6909
email: msantoro@tec.army.mil
web: http://www.tec.army.mil/OD/service.html
and go to Imagery Acquisition

LANDSAT TM

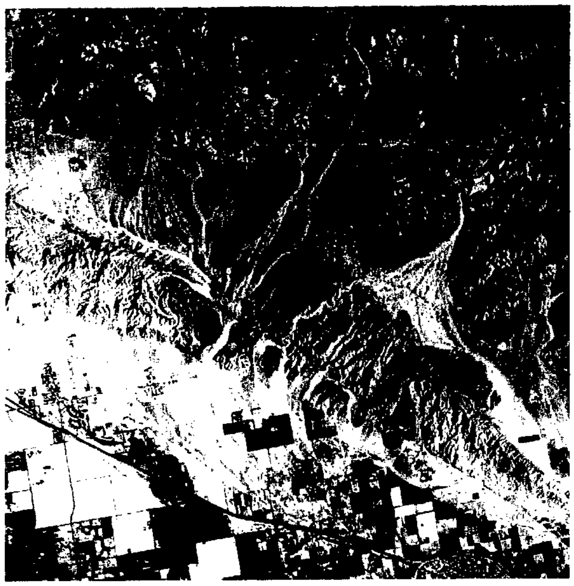

Image 2. Landsat TM imagery acquired over Joshua Tree National Park and Palm Springs, CA using 3-2-1 True-Color Band Comination.

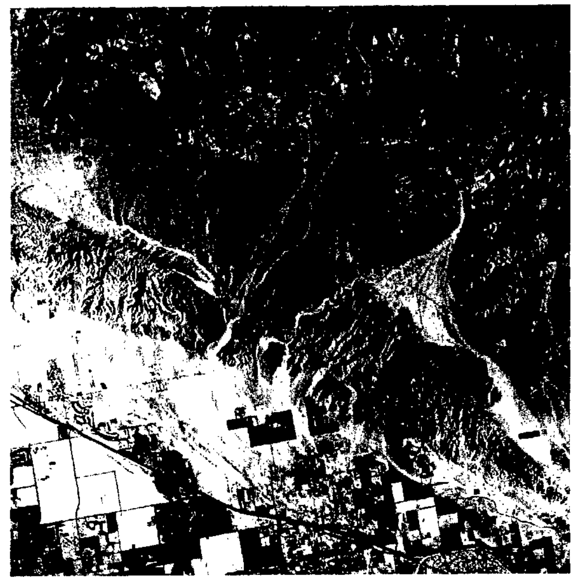

Image 3. Landsat TM imagery acquired over Joshua Tree National Park and Palm Springs, CA using 4-2-1False-Color Band Comination that emphasizes vegetation communities.

Sensor Specifications

Spatial Resolution: Bands 1-5 and 7 are 30-meter-square pixels;
Band 6, the thermal band, acquires 120-meter-square pixels.
Swath width: 185 km.
Revisit time: 16 days
Operational Dates: since March 1984

Wavelength Regions			
	0.45 to 0.52 *um* [blue]	0.52 to 0.60 *um* [green]	0.63 to 0.69 *um* [red]
	0.76 to 0.90 *um* [NIR]	1.55 to 1.75 *um* [SWIR]	2.08 to 2.35 *um* [SWIR]
	10.4 to 12.4 *um* [Thermal]		

General Discussion

Landsat TM can provide users with coarse scale imagery that covers large areas at a relatively low cost. Costs could be as low as $0 - $600 depending on the date of the imagery and if it was previously procured by another DoD agency. If extensive processing is required the costs may be $5,000 per frame.

Vendor Information

For more detailed vendor information contact:
contact:
Directorate
EOSAT's Customer Services Department
(301) 552-0537 or 1-800-344-9933 x537
email: custservices@eosat.com
web: http://www.eosat.com

or

EROS Data Center, USGS
User Services Section
Sioux Falls, SD 57198
Phone: (605) 594-6151 fax x6589
email: custserv@edcserver1.cr.usgs.gov
web: http://edcwww.cr.usgs.gov/webglis

US Army Civil Imagery Acquisition Program

For availability questions and purchasing
Topographic Engineering Center - Ops

7701 Telegraph Road
Alexandria, VA 22315-3864
Phone: (703) 428-6909 DSN 328-6909
email: msantoro@tec.army.mil
web: http://www.tec.army.mil/OD/service.html
and go to Imagery Acquisition

Landsat TM Data Grant Collection

The Landsat TM Data Grant Collection of over 500 scenes is available free to qualified U.S. Government and Affiliated Users. Other TM data may be available at approximately $425 to $600. Contact:
EDC DAAC User Services, EROS Data Center
Sioux Falls, SC 57198
Phone: (605) 594-6116 fax x6589
email: edc@eos.nasa.gov
web: http://edcwww.cr.usgs.gov

SPOT

Image 4. SPOT Panchromatic image acquired over Ft. Irwin, CA. Panchromatic imagery is primarily intended for applications requiring fine geometric detail.

Image 5. SPOT XS (multispectral) image acquired over Ft. Irwin, CA The infrared spectra emphasizes the vegetation communities.

Sensor Specifications

Spatial Resolution: 10-meters for the Panchromatic sensor
30-meters for the Multispectral sensor
Swath Width: 60 km
Revisit Time: 26 days for nadir view; 1-3 days off-nadir
Operational Dates: since February 1986

Wavelength Regions	Panchromatic	Multispectral
	0.51 to 0.73 *um*	0.50 to 0.59 *um* [green band]
		0.61 to 0.68 *um* [red band]
		0.79 to 0.89 *um* [near-infrared band]

General Discussion and Costs

SPOT imagery has a small footprint relative to MSS and TM and is good for seasonal green-up in arid-regions. Because the sensor can be pointed at areas of high interest, users can receive quicker revisit images and stereo capabilities. SPOT employs different levels of processing for its customers: Level 1A, Level 1B, and SPOTView. SPOTView is a precision-processed, GIS compatible, map projected product. SPOTView products are intended for GIS and image map applications. The next SPOT satellite, SPOT 4, is scheduled for launch in 1997. With an additional spectral band in the mid-infrared (MIR) range and a new vegetation instrument, the sensor will have improved capability for global monitoring of vegetation cover. Level 1A and 1B products, for an area approximately 60 km x 60 km, run upwards from $700 for film, $850 for print, and $2,000 to $2,800 for digital. The SPOTView products run from $1,000 on up to about $13,000 depending on the size of the area and the sensor used. Large area coverage is also available and is priced on a cost per-square-mile basis.

Vendor Information

For more detailed vendor information contact:
SPOT Image Corp.
1897 Preston White Drive
Reston, VA 22091-4368
Phone: 1-800-ASK-SPOT
(703) 715-3100 fax (703) 648-1813
email: creech@spot.com [Bill Creech, Defense Sales]
web: http://www.spot.com
also http://developers.ivv.nasa.gov/rem_sen/earth_sci/spot.html

U.S. Army Civil Imagery Acquisition Program

For availability questions and purchasing contact:
Topographic Engineering Center - Ops Dir
7701 Telegraph Road
Alexandria, VA 22315-3864
Phone: (703) 428-6909 DSN 328-6909
email: msantoro@tec.army.mil
web:http://www.tec.army.mil/OD/service.html
and go to Imagery Acquisition

STANDARD AERIAL PHOTOGRAPHY (NHAP/NAPP)

Image 6. A 1954 black & white photograph over Fairfax County, VA. Historical photography is useful for monitoring changes.

Image 7. A color infrared photograph over a portion of Huntley Meadows Park in Fairfax County ,VA

NHAP National High-Altitude Photography

Specifications

Spatial Resolution:
1:58000 [using CIR film and a 8.25-inch focal-length mapping camera flown at 40,000 ft above mean terrain]
1:80000 [using PAN film and a 6-inch focal-length mapping camera flown at 40,000 ft above mean terrain]
Revisit Times: Varied coverage over the 48 conterminous states
Flight Lines: Centered on the 1:24,000-scale USGS map series
Operational dates: Flown between 1980 and 1987

NAPP National Aerial Photography Program

Specifications

Spatial Resolution: 1:40,000 [using B&W or CIR film and a 6-inch focal-length mapping camera flown at 20,000 feet above mean terrain]
Revisit Times: Varied coverage over the 48 conterminous states
Flight Lines: Quarter quad-centered on the 1:24,000-scale USGS map series
Operational dates: Flown since 1987, as a follow-on to NHAP

NHAP/NAPP General Discussion and Costs

Standard aerial photography is used extensively for eastern forest and wetland mapping. Photographs are a high detail source for relatively small areas at a low cost. Conversely, a large number of photos would be required for large area analysis. Aerial photography additionally serves as a source of historical data useful for change detection analysis. Costs: $8.00 and up for black and white prints.

Vendor Information
For more detailed vendor information contact:
EROS Data Center
User Services Section
Sioux Falls, SD 57198
Phone: (605) 594-6151 fax x6589
custserv@edcserver1.cr.usgs.gov
web: http://edcwww.cr.usgs.gov/webglis

U.S. Army Civil Imagery Acquisition Program
For availability questions and purchasing contact:
Topographic Engineering Center - Ops Directorate
7701 Telegraph Road
Alexandria, VA 22315-3864
Phone: (703) 428-6909 DSN 328-6909 email:
email: msantoro@tec.army.mil
web: http://www.tec.army.mil/OD/service.html
and go to Imagery Acquisition

RADAR

Image 8. Radarsat image of clear-cut forests over Okanagan, Canada.

Image 9. IFSARE image over Sarajevo, Bosnia using color layers to depict elevation changes.

Radarsat International

Sensor Specifications

Spatial Resolution: 10 to 30-meter
Swath Width: 50-150 km
Revisit Time: Varies from two to nine days depending on sensor latitude and beam mode
Operational Dates: October 1995
Wavelength Region: C-Band SAR

General Discussion and Costs

Unlike optical sensors, the Radarsat microwave energy penetrates darkness, clouds, rain, dust, or haze, enabling data collection under any atmospheric condition. Capable of gathering data on ice conditions, crops, forests, oceans, and geology.
10 meter resolution images run from $3750 to $5250 for 50 km x 50 km area
30 meter resolution images run from $2750 to $4750 for 100 km x 100 km and 150 km x 150 km areas

IFSARE (Interferometric Synthetic Aperture Radar for Digital Terrain Elevation)

Sensor Specifications

Swath Width: 10 km
Operational Dates: Preliminary flights in 1996.
Wavelength Regions: X-Band capable of operating in all weather, day or night, and in the presence of obscurants.

General Discussion

IFSARE is an airborne radar system with accompanying ground processing equipment focused on quickly generating high density elevation data with 5-or 10-meter post spacing and 3 meter elevation and spatial accuracies.

Vendor Information

For more detailed Radarsat information contact:
Lockheed-Martin Astronautics
Deer Creek Facility P.O. Box 179
Denver, CO 80201
Cal Harr (303) 977-3938 fax x9827
email: cal.d.harr@den.mmc.com
or Radarsat International
web: http://radarsat.space.gc.ca
also //www.ccrs.nrcan.gc.ca/ccrs/radarsat/photos/radspece.html

Vendor Information

For more detailed IFSARE information contact:
Topographic Engineering Center - Tech. Directorate
7701 Telegraph Road, Alexandria, VA 22315-3864
Phone: (703) 428-6735 DSN 328-6735
email: pjohnson@tec.army.mil
web: http://www.tec.army.mil
U.S. Army Civil Imagery Acquisition Program
Phone: (703) 428-6909 DSN 328-6909
email: msantoro@tec.army.mil
web:http://www.tec.army.mil/OD/service.html

DIGITAL AERIAL ORTHOPHOTOGRAPHY
DIGITAL AERIAL ORTHOPHOTOGRAPHY WITH MULTISPECTRAL

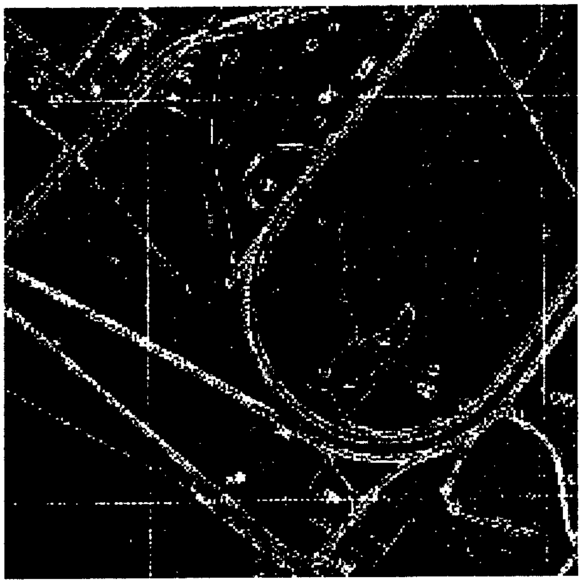

Image 10. Digital Aerial Orthophotography over Aberdeen Proving Ground. Very-large-scale photography enabled installation personnel to map vegetation, drainage, trails, and various cultural features on the installation. The imagery in the project can be used by all agencies at the base. More than 48,000 acres were mapped.

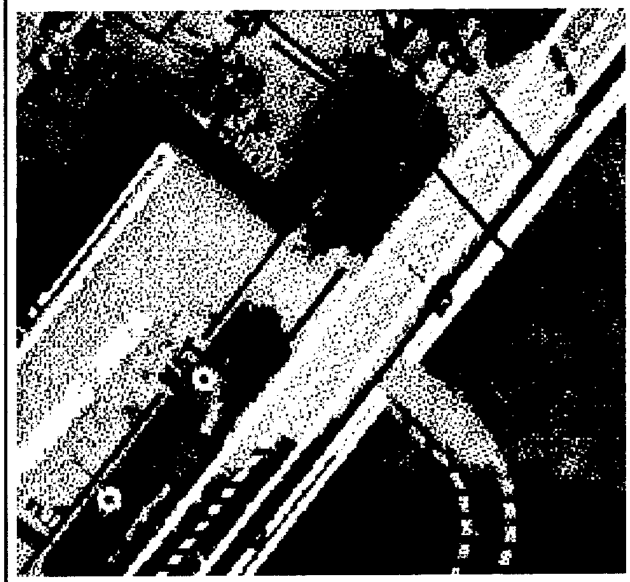

Image 11. Digital Aerial Orthophotography over Ft. Eustis, VA. Color-infrared and natural-color aerial photography were merged to delineate wetlands and other environmentally sensitive areas at Ft. Carson, CO. The work was part of a installation-wide Geographic Information Systems project.

<u>Sensor Specifications</u>
Spatial Resolution: variable
Swath Width: variable
Revisit Time: user-defined

<u>Spectral Resolution:</u>
Variable, relatively wide-band compared to individual satellite bands

<u>General Discussion and Costs</u>
Useful for wetland delineation in coastal and other DoD wetlands. Costs are variable depending on resolution, area, and level of processing. Higher costs are justified by the more accurate (i.e. rectified) images.

<u>Vendor Information</u>
For more detailed information contact:
William French, Executive Director
American Society for Photogrammetry and Remote Sensing
5410 Grosvenor Lane, Suite 210
Bethesda, MD 20814-2160
Phone: (301) 493-0290 fax x0208
email: billf@asprs.org

The images shown above were provided by Photo Science, Inc.
45 W. Watkins Mill Road
Gaithersburg, Md 20878
Phone (301) 948-8550
web: http://www.photosci.com

DIGITAL MULTISPECTRAL VIDEO (DMSV)

Image 12. Digital Multispectral Video image compiled using bands 0.75, 0.65, and 0.55 *um*. This combination shows the shoreline vegetation as well as the presence or absence of aquatic vegetation.

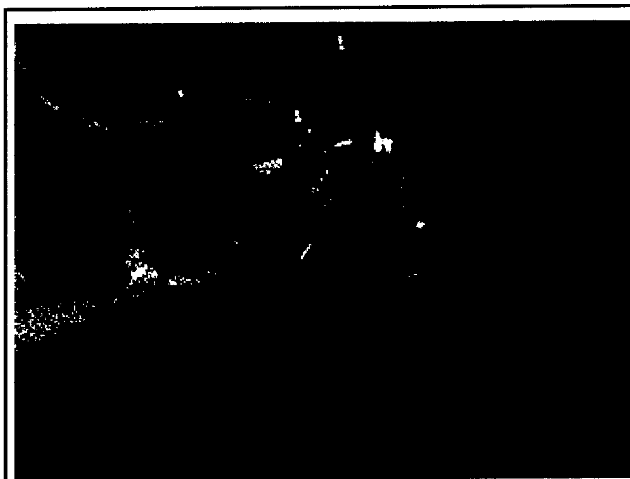

Image 13. DMSV image using a different combination of bands. Changing the band combinations to 0.77, 0.75, and 0.55 *um* shows density of aquatic vegetation.

<u>Sensor Specifications</u>

Spatial Resolution: Variable resolution (dependent on aircraft height) with a potential of 0.25 meters
Swath width: Variable from 300 to 550 meters
Revisit Time: User-defined

<u>Wavelength Sensitivity</u>

Four bands that are user selectable within the range of 0.350 *um* to 0.950 *um* [UV to VIS to NIR] with a band pass width greater than or equal to 0.010 *um*

Typical wavelength regions may be:

0.325 to 0.575 *um* [blue]	0.425 to 0.675 *um* [green]
0.525 to 0.775 *um* [NIR]	0.625 to 0.875 *um* [NIR]

<u>General Discussion and Costs</u>

The Digital Multispectral Video (DMSV) is being developed by Topographic Engineering Center. It has been used to delineate endangered species habitat, map wetland vegetation, measure reactions to stream acidification and study nutrient flow in wetland plant communities. DMSV imagery is typically used for customized applications and has a proven high capability in mid-Atlantic aquatic/wetland studies. The selectable bandwidths offer high spatial and high spectral resolution. Frame processing costs $25-50. Travel and setup costs are extra. High cost for large areas.

<u>Vendor Information</u>

For more detailed information contact:

Topographic Engineering Center - Technology Directorate
7701 Telegraph Road
Alexandria, VA 22315-3864
John Anderson Ph.D., Research Biologist
phone: (703) 428-8203 DSN 328-8203
email: johna@tec.army.mil

Fact Sheet #8

EARTHWATCH, INC.

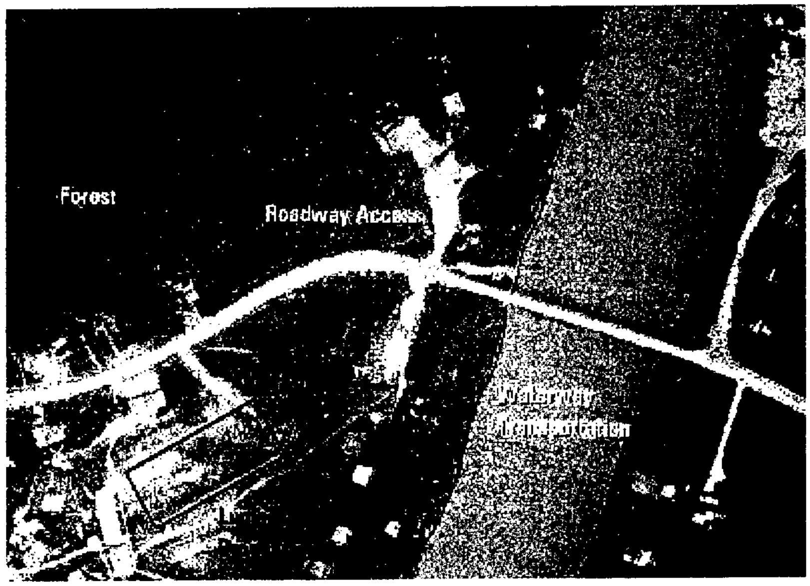

Image 14. This EarthWatch image depicts natural and cultural resource information required to locate a suitable lumber processing site.

Sensor Specifications

	EarlyBird Satellite Panchromatic Sensor	QuickBird Satellite Panchromatic Sensor
Spatial Resolution:	3 meters	1 meter
Wavelength Region:	0.45 to 0.80 *um*	0.45 to 0.90 *um*

	EarlyBird Satellite Multicolor Sensor	QuickBird Satellite Multicolor Sensor
Spatial Resolution:	15 meters	4 meters
Wavelength Regions:	0.50 to 0.59 *um* [green]	0.45 to 0.52 *um* [blue]
	0.61 to 0.68 *um* [red]	0.53 to 0.59 *um* [green]
	0.79 to 0.89 *um* [NIR]	0.63 to 0.69 *um* [red]
		0.77 to 0.90 *um* [NIR]

Revisit: The EarthWatch system will revisit most populated parts of the world 2-3 times per day.
Operational Dates: First satellite is scheduled to be launched in late 1996, the fourth satellite is scheduled to be launched in mid-1999.

General Discussion

The EarthWatch system will be composed of two 3-meter resolution EarlyBird satellites and two 1-meter resolution QuickBird. This density of coverage will allow nearly daily coverage of each point on the earth.

Vendor Information

For more detailed EarthWatch, Inc. information contact:
EarthWatch, Inc.
1900 Pike Road
Longmont, CO 80501-6700
POC: Ron Birk (Director, Civil Government Marketing)
Phone: (303) 682-3800 fax x3848
web: http://www.digitalglobe.com

U.S. Army Civil Imagery Acquisition Program

For availability questions and purchasing:
Topographic Engineering Center - Ops Dir.
7701 Telegraph Road
Alexandria, VA 22315-3864
Phone: (703) 428-6909 DSN 328-6909
email: msantoro@tec.army.mil
web:http://www.tec.army.mil/OD/service.html
and go to Imagery Acquisition

SPACE IMAGING, INC.

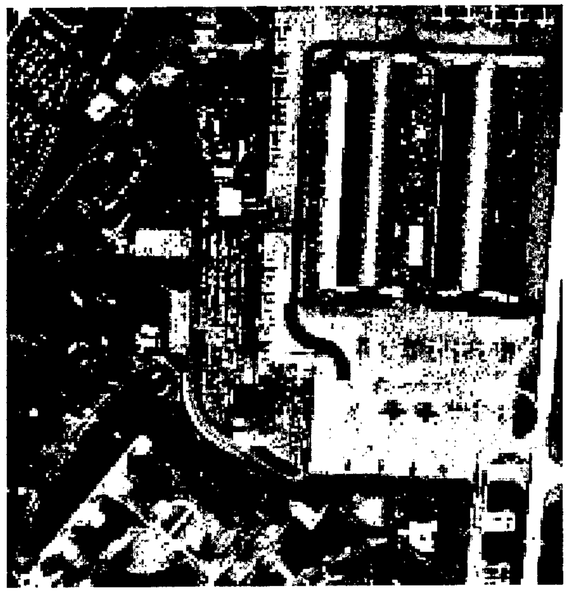

Image 15. Pan-sharpened multispectral data at 1-meter spacing. This image was collected over Moffett Naval Air Station.

Sensor Specifications

	Panchromatic Sensor	Multispectral Sensor
Spatial Resolution:	1 meter	4 meters
Wavelength Region:	0.45 to 0.90 *um*	0.45 to 0.52 *um* [blue]
		0.52 to 0.60 *um* [green]
		0.63 to 0.69 *um* [red]
		0.76 to 0.90 *um* [NIR]

Swath Width: Images will cover areas of 11 km x 11 km, but smaller or larger areas can be purchased.
Revisit Time: 2-4 days
Operational Dates: The Space Imaging satellite is scheduled to be launched in 1997.

General Discussion

Prior to ordering products, customers can review reduced-resolution "browse" imagery in the Space Imaging archive that meets specific criteria such as geographical location, maximum cloud cover, time of image collection, ground sample distance, and where appropriate, mono and stereo views. Products will include radiometrically corrected images; geometrically corrected images, orthorectified images made from one-meter pan imagery that meet the U.S. National Map Accuracy Standards for map scale accuracy up to 1:2400; pan-sharpened color imagery; and digital terrain models generated from stereo image pairs.

Vendor Information

For more detailed Space Imaging, Inc. information contact:
Space Imaging, Inc.
9351 Grant Street, Suite 500
Thornton, CO 80229-0939
Phone: (800) 425-2997 or (303) 254-2000
email: info@spaceimage.com
web: http://www.spaceimage.com

U.S. Army Civil Imagery Acquisition Program

For availability questions and purchasing:
Topographic Engineering Center - Ops Dir
7701 Telegraph Road
Alexandria, VA 22315-3864
Phone: (703) 428-6909 DSN 328-6909
email: msantoro@tec.army.mil
web:http://www.tec.army.mil/OD/service.html
and go to Imagery Acquisition

V. PROCUREMENT

A. Important First Steps in Acquisition

Sources of remote sensing imagery may be closer and cheaper than you think. After determining that you need imagery, don't assume that you need to go to the nearest vendor to procure it.

There are several sources that should be checked prior to making a purchase:

Imagery may have already been purchased by someone on your installation.

- Check your own file drawers, closets, in and under desks... (sometimes you don't know what YOU have until you look)! Consider this a good time to make an inventory list.
- Facilities / Master Planners
- Local or Federal agencies that have field offices on the installation

Imagery may have already been purchased by an organization near your installation.

- Look in the phone book, ask people who have worked in the area for a long time; if you don't already know what organizations border your installation, find out! They can be your allies when you need imagery and various other types of assistance.
- Aerial photos from federal agencies are archived at the USGS EROS Data Center. Participating agencies include Bureau of Indian Affairs, Bureau of Land Management, Bureau of Reclamation, Environmental Protection Agency, Nation Park Service, National Aeronautical Space Administration, U.S. Air Force, U.S. Army, and U.S. Navy. Coverage, dates, scales, and available products vary by agency. USGS EROS Data Center: (605) 594-6151; http://edcwww.cr.usgs.gov/glis/hyper/guide/govtphotos#gp1.

Up-to-date imagery may be needed by others in your area.

- Ask installation tenants and organizations, and off-post organizations if they are interested in sharing the costs of imagery acquisition. Remote sensing images can cover large areas and may be useful to others. If an aerial photo mission is necessary, costs can be greatly reduced by flying one mission for two organizations. Even though Facilities organizations require photos at different resolution than the Natural Resources offices, costs are reduced by combining the missions. The contractor can meet the needs of both organizations during the same mission and have to put the plane in the air only once.

Once determining that you need to procure imagery, there are sources for assistance listed in the following section; it never hurts to get a second opinion! Sample Statements of Work (SOW) are also included.

B. Imagery Acquisition Assistance

1. Conservation Assistance Program :

Installation land managers seeking general remote sensing advice can contact the Army's Conservation Assistance Program (CAP). CAP provides rapid-response, short-duration support to installation natural and cultural resource managers. Expertise from Corps of Engineers Laboratories and other Federal Agencies is available to installations through this program. USAEC is currently providing funding for this assistance; amounts vary by project and are subject to availability. Requests must be within the guidelines of the program. For more information, call ***Steve Getlein, CAP Coordinator, U.S. Army Environmental Center at DSN 584-1592 or COM (410) 671-1592, or Internet sgetlein@aec.apgea.army.mil.*** Alternatively, call the USAEC Environmental Hotline 1-800-USA-3845 or DSN 584-1699 (ask for the CAP Program Coordinator).

2. Nearby installations / agencies:

Consider contacting nearby installations or other federal agencies for information or assistance. They may be able to help with regional remote sensing problems and provide references to other land managers who may have dealt with similar issues.

3. Army Civil Imagery Acquisition Program:

For assistance in acquiring imagery, contact the U.S. Army Civil Imagery Acquisition Program, a data acquisition service operated by the Topographic Engineering Center's Operations Directorate. The program serves as a repository of selected civil imagery pertaining to terrain analysis and water resources analysis and operations. Most importantly for natural resource and installation managers, this Directorate is the Army's civil imagery monitor for all DoD purchases of civil imagery. This source can help you find a wide range of imagery, select the most useful imagery, and procure it at the lowest cost. Contact ***Mary Pat Santoro (703) 428-6909, DSN 328-6909, msantoro@tec.army.mil.***

C. *Statements of Work*

Statements of Work (SOWs) for remote sensing products define the bounds of the area to be studied, the platforms to be used, the degree of accuracy required, scale of imagery and resulting products, and processing that adds value (and costs) to the basic imagery. SOWs, properly written, eliminate much potential misunderstanding, and allow for periodic checks during the course of the project. They are also useful when discussing the end of a project, or if conflicts between contractor and customer arise during or after a project's completion.

Several SOWs follow this brief summary. They include tasks that are common to most custom aerial photography or satellite imagery acquisition efforts. They include:

Areal extent: How large is the area for which you are seeking aerial photography, or satellite or other imagery?

Scale: How much detail do you want in your imagery is a decision that comes from you final needs. Do you need to be able to find headwater streams, larger streams or just large rivers? Do you want to delineate wetlands at fine scales? Are you looking for forest stress caused by insects or disease? The key found in this report can help you estimate the scale you need to work with.

Possible additional uses of imagery? Will you use the imagery for follow-on or other natural resource management projects, for example change-detection, cultural resource management or other applications? If so, you may want to consider paying more now for additional imagery that will increase later value of the data set.

Temporal scale: Is this a one-time acquisition, or should you think about multiple images to show change over time? You may be able to save money by asking for later acquisitions at the time of initial purchase.

Output product: On which media or format do you want the final imagery product; in hard-copy form, on a diskette, a tape, a CD-ROM, or some combination of these? Choosing the proper media now can increase the chances of sharing the data, increase compatibility with current and potential future systems, and increase the probability that the data will actually be used to address management problems.

Cost: What will this project cost? What could happen to increase the cost, both from the point of view of changed requirements on the part of the customer, and unforeseen problems for the contractor or service provider?

1. Statement of Work - Example 1

DELIVERY ORDER NUMBER 17
CONTRACT NUMBER DACW65-93-D~094
AERIAL PHOTOGRAPHY, PLANIMETRIC MAPPING
AND DIGITAL ORTHOPHOTOGRAPHY
FORT EUSTIS, VIRGINIA

1. GENERAL

The Statement of Work (SOW) for this delivery order is for the contractor to provide horizontally and vertically controlled aerial photography, in natural color and false color infra-red film, contact prints and 100 scale planimetric mapping of the cantonment area and Felker Army Airfield, Fort Eustis, Virginia. Horizontal control shall be based on the Virginia State Plane Coordinate System (South Zone) North American Datum of 1983 (NAD 1983) and Vertical Control shall be based on the National Geodetic Vertical Datum of 1929, 1972 adjustment (NGVD 1929, 1972 adjustment).

2. DETAILED STATEMENT OF WORK

The contractor shall fly 1" = 2000' false color infra red and 1" = 500' natural color film over the entire area of Fort Eustis, Virginia. From the 500 scale photography the contractor shall prepare 1~ = 100' planimetric mapping of the area outlined on attachment 1 to this SOW. Planimetric features to be captured include but may not be limited to: building footprints, roadways, railroads, hydrography and above ground storage tanks. In addition, personnel at Fort Eustis shall paint all ground and above ground utilities in accordance with the sketches shown on attachment 2 to this SOW. The contractor shall capture this utility information as part of his work in performing the planimetric mapping. These utilities shall include: storm sewer manholes, sanitary sewer manholes, telephone manholes, water valves, gas valves, fire hydrants, catch basins, drop inlets, storm sewer outfalls and monitoring wells. Fort Eustis will furnish to the contractor a set of prints of the existing 100 scale mapping and the contractor shall cover the identical areas with the new 100 scale mapping. The contractor shall generate digital files of the mapping data in a format compatible with the Fort Eustis CADD system currently being installed (Intergraph). From these digital files the contractor shall plot the information on 42" x 30" mylar sheets with the Fort Eustis DPW title block which shall be furnished to the contractor in digital form.

Initial consulting services shall be provided by the contractor to develop technical specifications and an operations manual to implement a basic Geographic Information System (GIS) compatible with Fort Eustis's CADD system. This system shall incorporate the existing IFSM database into the CADD system. Additional consulting services shall be provided to ensure the Fort Eustis GIS is immediately able to provide useful base data and is structured to allow for its efficient growth and development. These services shall include: review of existing hard copy map data, develop a GIS implementation plan, base map data integration and IFSM database integration.

3. OPTIONAL WORK ITEMS

Option 1. Prepare 1 " = 400' digital orthophotography from the 1" = 2000' FCIR photography in basic work.

Option 2. Prepare 1" = 100' digital orthophotography from the 1" =500'.natural color photography in basic work

Option 3. Wetlands, land use and land cover mapping using 1" = 400' FCIR digital orthophotography

Option 4. Natural color photography at 1" = 250' scale over entire installation. Horizontally and vertically controlled.

Option 5. Additional FCIR photography at 1" = 2000' scale over entire installation after full leaf out. Horizontally and vertically controlled, aerotriangulation included.

Option 6. Digital orthophotography of the entire installation at 1" = 400' FCIR of option 5.

Option 7. Digital orthophotography/topographic mapping of the entire installation or selected "hot spots" at 1" = 50' scale with 1 foot contour interval. Because of the expected magnitude of this option, for the entire installation, it shall remain unpriced until the "hot spots" can be determined.

Option 8. Additional consulting services to include: tabular database development and data input for environmental applications, research historic imagery for toxic/munitions sites and input data into GIS and research location of historic archeological sites and input into GIS.

The Government reserves the right to exercise any and/or all optional work items above for a period of two hundred seventy (270) calendar days after receipt by the contractor of the Notice to Proceed with the basic work of this delivery order. If option 4 is exercised with the basic delivery order a reduction in the cost of option 4 will be required. Control and aircraft miles will need to be eliminated from the option price.

4. SUBMISSION REQUIREMENTS AND SCHEDULE

At the completion of work the contractor shall submit to the Government the following items:
a. 2 sets of contact prints of all aerial photography
b. Digital files of all mapping data, Intergraph compatible, 3 1/2" disks
c. 1 set of mylar plots, 100 scale mapping, 42" x 30" sheets
d. Technical specifications and operations manual for GIS system

These items shall be delivered by the contractor according to the following schedule:
a. Contact prints within 30 calendar days from receipt by contractor of Notice to Proceed
b. Digital files, maps and manual within 180 calendar days from receipt by contractor of Notice to Proceed.

5. OTHER REQUIREMENTS AND CRITERIA

The following information has been or will be furnished to the contractor prior to work beginning on the delivery order:

a. Descriptions, coordinates and elevations of horizontal and vertical control monuments in the area

b. Copies of the existing 100 or 400 scale planimetric maps for the cantonment area at Fort Eustis to determine area of coverage.

All work on this delivery order shall be accomplished in accordance with Corps of Engineers criteria for surveying and mapping and EM1110-1-1000, 31 March 1993, PHOTOGRAMMETRIC MAPPING.

2. Statement of Work - Example 2

DELIVERY ORDER NUMBER 4
CONTRACT NUMBER DACW65-95-D-0080
AERIAL PHOTOGRAPHY, CONTROL AND
DIGITAL ORTHOPHOTO MAPPING
MARINE CORPS BASE, QUANTICO, QUANTICO, VIRGINIA
FEBRUARY 9, 1996

1. GENERAL

The Statement of Work (SOW) for this delivery order requires the contractor to provide horizontally and vertically controlled (using both ground and airborne GPS control) natural color photography and 1" = 200' scale digital orthophoto mapping of Marine Corps Base, Quantico. Horizontal control shall be based on the Virginia State Plane Coordinate System (North Zone) North American Datum of 1983 (NAD1983, 1986 adjustment) and vertical control shall be based on the National Geodetic Vertical Datum of 1929, 1972 adjustment (NGVD1929, 1972 adjustment)

2. DETAILED STATEMENT OF WORK

The contractor shall acquire one inch equals 1,200 feet scale natural color photography over the entire area of Marine Corps Base, Quantico. Using this photography and the associated ground and airborne GPS control data, the contractor shall perform an aerotriangulation adjustment to generate sufficient photo control to produce the final orthophotos. The contractor shall also develop Digital Elevation Models ~ DEM) to support the orthophoto map scale. Using these inputs, the contractor shall prepare 1 inch equals 200 feet digital orthophoto mapping of the base. The digital orthophoto mapping shall have a ground pixel resolution of 1.5 feet or better. The contractor shall also convert the state plane coordinate system horizontal datum to the Universal Transverse Mercator conic projection values, WGS84 adjustment. All final digital orthophoto data sets shall be delivered to the government in Arc/Info and Intergraph compatible formats on CD's.

Optional Work: A suitable scale for wall hanging digital file mosaic shall be made from the digital orthophoto files covering the entire base.

3. SUBMISSION REQUIREMENTS AND SCHEDULE

The contractor shall commence work on this delivery order within 10 calendar days after the receipt by him of the Notice to Proceed (NTP). 60 calendar days after the photo mission is flown 1 set of 9" X 9" color contact prints of all photographs shall be delivered to Mr. Jeff Shrum at Quantico. 120 calendar days after receipt by the contractor of the NTP he shall deliver two (2) draft mapping files to Mr. Shrum to determine compatibility of digital files delivered with the computer system at Quantico. 180 calendar days after receipt by the contractor of the NTP he shall deliver all final digital orthophoto mapping files to Mr. Shrum at Quantico Marine Corps Base. All digital files shall be delivered on high quality compact disks, CD's.

Deliverables:
a. One set of 9" X 9" color contact prints
b. One flight line index
c. Aerotriangulation adjustment report
d. Digital orthophoto data sets two (2) copies each in Arc/Info and Intergraph compatible formats
e. Digital Elevation Models in ASCII format
f. Color mosaic of entire base

4. OTHER REQUIREMENTS AND CRITERIA

All work on this delivery order shall be accomplished in accordance with National Map Accuracy Standards, Corps of Engineers criteria for surveying and mapping and EM1110-1-1000, 31 March 1993, PHOTOGRAMMETRIC MAPPING.

3. Statement of Work - Example 3

DELIVERY ORDER NUMBER 5
CONTRACT NUMBER DACW65-95-D-0080
AERIAL PHOTOGRAPHY, CONTROL AND
DIGITAL ORTHOPHOTO MAPPING
FORT A. P. HILL, CAROLINE COUNTY, VIRGINIA
MARCH 27, 1996

1 GENERAL

The Statement of Work (SOW) for this delivery order requires the contractor to provide horizontally and vertically controlled (using both ground and airborne GPS control) natural color photography and 1" = 200' scale digital orthophoto mapping of Fort A. P. Hill, Caroline County, Virginia. Horizontal control shall be based on the Virginia State Plane Coordinate System (North Zone) North American Datum of 1927 (NAD1927) and vertical control shall be based on the National Geodetic Vertical Datum of 1929, 1972 adjustment (NGVD1929, 1972 adjustment)

2. DETAILED STATEMENT OF WORK

The contractor shall acquire one inch equals 1,200 feet scale natural color photography over the entire area of Fort A. P. Hill. Using this photography and the associated ground and airborne GPS control data, the contractor shall perform an aerotriangulation adjustment to generate sufficient photo control to produce the optional orthophotos. The contractor shall produce from this photography four sets of color contact prints, a photo index and ground control tabulation. A brief description showing location for each control point shall also be prepared. Using these inputs, the contractor shall prepare 1 inch equals 200 feet digital orthophoto mapping of the base. The digital orthophoto mapping shall have a ground pixel resolution of 1.5 feet or better. The contractor shall also convert the state plane coordinate system horizontal datum to the Clark 66 Universal Transverse Mercator conic projection values. All final digital orthophoto data sets shall be delivered to the government in Color View/TifWorld or AutoCADD compatible formats on CD's. The contractor shall also develop Digital Elevation Models (DEM) to support the orthophoto map scale

3. SUBMISSION REQUIREMENTS AND SCHEDULE

The contractor shall commence work on this delivery order within 10 calendar days after the receipt by him of the Notice to Proceed (NTP). 60 calendar days after the photo mission is flown 4 set of 9" X 9" color contact prints of all photographs shall be delivered to Mr. John Phillips at Fort A. P. Hill. The contractor shall deliver 120 calendar days after receipt by the contractor of the NTP two (2) draft mapping files to Mr. Phillips to determine compatibility of digital files delivered with the computer system at Hill. 180 calendar days after receipt by the contractor of the NTP he shall deliver all final digital orthophoto mapping files to Mr. Phillips. All digital files shall be delivered on high quality compact disks, CD's.

Deliverables

a. Four sets of 9" X 9" color contact prints, 1,240 prints
b. One flight line index, showing control points used
c. Description and coordinates of control points
d. Aerotriangulation adjustment report
e. Two copies Digital orthophoto data sets
f. Digital Elevation Models in ASCII format

4. OTHER REQUIREMENTS AND CRITERIA

All work on this delivery order shall be accomplished in accordance with National Map Accuracy Standards, Corps of Engineers criteria for surveying and mapping and EM1110-1-1000, 31 March 19g3, PHOTOGRAMMETRIC MAPPING.

VI. SUPPLEMENTAL REMOTE SENSING INFORMATION

A. What Remote Sensing Can Do

1. Show changes in the resource base
2. Detect impacts such as erosion, disease, fire extent
3. Estimate areal extent of impacts
4. Delineate wetlands, wildlife habitats and floodplains
5. Plan wildlife corridors and mitigation projects
6. Minimize training impacts
7. Map vegetation in impact areas and other denied areas
8. Give managers an overall view of their installations

B. New Image Types

Remote sensing has been used by the military at least since the use of balloons for mapping enemy lines during the Civil War. Color infrared photography has emerged as a standard assessment tool for natural resource managers. Spaceborne sensors such as Thematic Mapper and SPOT are increasingly used to detect change in forests, water resources, rangelands, and other natural resources. New sensor developments include:

- Digital Aerial photography
- Aerial color video
- "Merges" of several imagery types
- Raster (image) and vector (point/line) merges

Land managers now have greater power to conduct baseline inventories and detect change.

C. Image Interpretation

Image interpretation is the process of identifying objects or conditions on remotely sensed images and inferring their significance (Avery et. al., 1992). Since the late 19th century viewing imagery and distinguishing subtle differences in brightness and darkness, textures, depth perception and recognizing complex shapes and feature has become a part of our everyday life. However, image interpretation requires conscious, explicit effort not only to learn about the subject matter, geographic setting and imaging systems in unfamiliar contexts, but also to develop our innate abilities for image analysis (Campbell, 1987).

Three Ways in Which Remote Sensing Differs from "Real" Life:

1. Imagery is usually acquired from overhead; not too many family photos are taken from this perspective (except perhaps by bungee jumpers).
2. Many sensors record imagery beyond the visible portion of the electromagnetic spectrum. A Color Infrared image of healthy vegetation will appear red rather than green.
3. Imagery may be acquired at unfamiliar resolutions and scales. Familiar objects on a high resolution photo may not be recognizable on a coarse MSS image (Campbell, 1987).

When interpreting imagery, there are a number of characteristics that enable the viewer to detect, recognize or even identify objects from the vertical imagery. These recognition elements are: shape, size, pattern, shadow, tone or color, texture, association and site (Avery et al., 1992, Campbell, 1987, Simonett, 1983).

The **shape** of an object is described as the geometric form represented on an image. Regular shapes, squares, rectangles and circles are signs of man-made objects, e.g., buildings, roads, and cultivated fields. Irregular shapes, with no distinct geometrical pattern are signs of a natural environment, e.g., a wetland area. Dr. Koeln, in Applications of Satellite Data for Mapping and Monitoring Wetlands (1992), states in order to make proper use of data collected from a remotely sensed platforms that the "various dependent variables from the satellite data are needed such as area of basin (size) length of basin perimeter (element of size), shape, and square and cubic transformations of these variables."

Shape was one of four elements of object recognition used by Carter et. al., (1979) to identify and classify wetlands in the Tennessee Valley area. The shapes of wetlands in Carter's Tennessee Valley area project were not as regular as wetlands in the Prairie Pothole region, which are often circular. Where tone is temporally dependent, shape tends to be geographically dependent.

Size describes the two-dimensional measurement of a given object. If the interpreter knows the dimensions of an object, it might be possible to identify that a rectangular object on an image is a football field, if the image's scale is known. Relative size is also important in differentiating between objects of the same shape. Avery et. al., (1992) argues that "there is a relative size difference between a house and an apartment building and between multiple-lane and single-lane streets."

Pattern refers to the repetition of some form over space. A pattern on an image usually illustrates "a functional relationship between the individual features that compose the pattern" (Campbell, 1987). In nature, for example, naturally dispersed trees are randomly spaced, versus the orderly distribution of trees in an orchard.

Shadows cast due to low sun angle are important to imagery interpretation, because their shapes provide profile views of certain features that can aid in their identification. Shadows can also obscure detail. In dense urban environments, for example, shadows might hinder the identification of certain shapes and patterns. On the other hand, shadows might aid in the identification of certain objects like bridges, transmission towers and water towers.

Tone denotes the lightness or darkness of a feature in an image. Color refers to the reflective characteristics of objects within the photographic spectrum. The reflected radiation of an object is dependent on its "surface composition and physical state plus the intensity and angle of illumination" (Avery et. al., 1992). Carter et al. (1979) used tone to separate the various wetland classes in the Tennessee Valley area. Carter argued that tonal difference can be dependent on seasonality. In order to determine evergreen/deciduous boundaries, winter photographs were necessary. Forested swamp, for example, appeared blue-green with some red & yellow in October, dark brown in February, and dark blue in November using high-altitude color infrared photography. To detect excess soil moisture, which aids in the demarcation of wetlands, Nixon et. al., (1987) states "... inundated or wet low field areas produced a dark bluish color... and ... wet soil conditions were distinctively evident in the infrared image (videography) in which the areas gave a dark and dull gray appearance."

Texture refers to the visual impression of the roughness or smoothness of an image region. Texture is often used to identify objects that are too small to resolve individually, i.e., tree leaves and leaf shadows. Howland (1980) claims that "texture, pattern and the height of the canopy were for many (wetland) signatures the differentiating factors".

"Identification of certain objects . . . {is usually accomplished} . . through their **association** with other known objects. Sometimes the reverse is true because some objects are rarely, if ever, associated with the other." (Mbobi, 1992) Stewart et al., (1980) applies association to identify small wetlands by correlating that the "absence of trees in the citrus groves serves to indicate the low spots in this karst topography because citrus trees will not thrive in places where water will stand for even a short period of time".

D. General Remote Sensing Terminology

Ten remote sensing data sources are presented in the sensor matrix and are referenced in the ecoregion-organized Selection Key of this guide. The matrix references the various specifications as defined in this section.

"The major characteristics of an imaging Remote-Sensing instrument operating in the visible and infrared spectral bands are described in terms of its spatial, temporal, spectral and radiometric resolution. Other important features are the manner of operation of the scanning devices (electromechanical or electric) and its geometrical properties." (Mather, 1987) The four elements of spatial resolution are: geometrical properties of an imaging system; the ability to distinguish between point targets; the ability to measure the periodicity of targets; and the ability to measure the spectral properties of small objects.

The **instantaneous field of view (IFOV)** of a sensor is one way to measure the geometrical properties of an imaging system. The IFOV represents the area of ground, viewed by the instrument from a given altitude at any given time. It can be measured in one of two ways: as angular measurement or the area on the ground. Because the actual altitude of a platform may vary, the spatial resolution will vary accordingly. As the altitude of a platform decreases the area of the ground (Pixel size) observed will also decrease. The spatial resolution of Landsat's-1 to -3 multispectral scanner, for example, is reported as 79 meters. The actual resolution varies from 76 to 81m.

Defining **spatial resolution on the IFOV** does not take into account the spectral properties of the target. Determining "the size of an area for which a single radiance value can be assigned with reasonable assurance that the response is within 5 percent of the value representing the actual relative radiance" (Simonett, 1983) is known as the effective resolution element (ERE) of a platform. Other methods focus on the spatial resolving power of a detector depend on the ability of the detector to distinguish between specified targets. The resolution is expressed in terms of lines pairs per millimeter on the image.

Spatial resolution can also be thought of in terms of the **ground surface distance (GSD)** capability of the sensor. GSD for an image is comparable to the minimum mapping unit for a map. A rough but useful rule to use when selecting imagery to discern attributes of given size is that the sensor must be able to detect objects one-half the size of the object to be identified (i.e., if you want to be able to find something 20 meters in size, you must have imagery that collects data in pixels 10 meters square.)

Except for a few microwave emitting platforms, recent sensors have **been multi-band or multi-spectral**. This means that an image is recorded in discrete spectral bands. Spectral resolution refers to the width of these spectral bands. Individual bands and their widths "will determine the degree to which individual targets (vegetation species, crop or rock types) can be discriminated on a multispectral image. The use of multispectral imagery can lead to a higher degree of discriminating power than any single band on its own. (Mather, 1987)

The **spectral resolution** of a remote sensing instrument is determined by the bandwidths of the channels used. "High spectral resolution is achieved by narrow band widths which, collectively, are likely to provide a more accurate spectral signature for discrete objects than broad band widths." (Simonett, 1983) Higher spectral resolution reduces the signal-to-noise ratio of the data collected.

Pushbroom scanners, for example, look at each scan line longer "and this gives a better signal-to-noise ratio than does the mechanical scanner which has a single detector which observes each scan line element sequentially. The time available to look at each point is therefore greater for the Pushbroom scanner, thus narrower bandwidths and a larger number of quantization levels are theoretically possible without decreasing the signal to noise ratio to unacceptable levels" (Mather, 1987)

The **radiometric resolution** of a sensor is determined by its sensitivity to different levels of reflected electromagnetic radiation. For example, Landsat TM detectors produce Digital Number (DN) values that range from 0 to 255. The number of DN values are expressed in terms of the number of binary digits of bits needed to store the value of the maximum DN values. This gives Landsat's TM sensor a radiometric resolution of 8 bits. Higher radiometric resolution does not mean a higher quality image. Slater (1980) illustrates that the signal to noise ratio decreases with the increase of radiometric resolution. Tuker (1979) showed that there was only a 2 to 3% gain in distinguishing vegetation types using a 8-bit resolution vis a vis 6-bit resolution.

Temporal resolution is the frequency of repeat coverage. Hence, low temporal resolution refers to a platform that infrequently repeats coverage. Whereas high temporal resolution refers to a platform that frequently repeats coverage. Simonett (1983) argues that with some applications, temporal resolution is an important factor. For example, to monitor crop growth/stress, image intervals of 10 days would be required, but one year intervals would be appropriate to monitor urban growth patterns.

False Color Band Combinations: Image analysts possess a variety of techniques that can be used to artificially increase the difference between attributes in an image. In Landsat imagery, for example, analysts can change the selection of bands displayed to emphasize attributes they want to study. Similarly, color and texture patterns within images can be emphasized (at the cost of distorting the information contained in the image). While several sophisticated image-processing systems make this technique easier to intermittent users, these techniques deliver increased analytical power at a cost of increased jeopardy of creating "artifacts" in the image that are not indicative of on-the-ground attributes but are rather creations of the image-processing process.

E. Aerial Photography: Types and Exploitation

Aerial photography is perhaps the oldest remote-sensing technology. It is available in a wide variety of resolutions (scales), film types, and dates. It can be acquired as digital information, transparencies or paper prints. It is an inexpensive, widely available source of natural-resources information.

A 1:2400 photography depicts one inch of photograph for every 2,400 inches (200 feet) of ground. A 1:60,000 image depicts one inch of photograph for every 60,000 inches (5,000 feet). The compromise every photo-interpreter makes is choosing between multiple scales to provide the greatest amount of detail in the image while covering enough ground to detect patterns: literally, in some cases, being able to see the forest for the trees.

Aerial photography is available from many sources. There is a central source for federal photography (details may be found in fact sheet number four in this report). Non-federal holders of aerial photography include state and local transportation departments; private forestry and engineering/consulting companies; local, regional and state planning commissions and agencies; historical commissions, and construction companies.

Many installation offices have acquired aerial photography. Some offices may have historical photography that could prove to be an inexpensive and extensive aid to determining baseline condition and detecting changes in natural resources.

Black-and-white photo film was the first widely used aerial photography film. Black-and-white film records images across roughly the same spectral range our eyes record. Black-and-white records well through haze filters. Speed can be manipulated to acquire usable images in special light conditions. Color film usually requires more light than does black-and-white to provide usable images. Since people can "see" more color gradations than they can gray tones, color photos typically allow greater interpretation of features with small tonal changes. Color infrared is the dominant vegetation-interpretation film. It can highlight small color changes, often invisible to the unaided eye, in plant vigor caused by stress such as disease, drought and insects. Color-infrared aerial photography is a widely available source of vegetation condition and extent. Sets of color-infrared photos acquired during several growing season may be available through an installation or regional forester.

F. Technology Transfer

Very few people are able to use remotely sensed imagery productively without at least some training. A logical follow-on to this guide would be a series of short courses or tutorials (2-5 days) designed to acquaint military natural resource managers with the imagery described in this guide and the manual and digital imagery-analysis techniques needed to exploit that imagery. The Defense Mapping School offers courses that are close to meeting that description. Many universities and colleges offer courses of varying length that focus on remote sensing; the more hands-on exercises that are offered, the more beneficial the course.

New satellites have the potential for acquiring near-real-time, cost-effective, high resolution imagery; however, that potential will only be exploited by users who understand it. After taking a basic remote sensing course, resource managers should be able to study promotional literature from imagery vendors and ascertain from demonstration data sets whether the new imagery is appropriate for their needs.

G. *Recommendations for Future Editions*

Several potential follow-on activities were identified during the writing of this report. They include:

1. **To add a section on "how-to" advice for digital imagery analysis.** This section would include a brief summary of manual imagery analysis techniques. As Army natural resource managers increasingly exploit digital data and imagery sources, a how-to guide for digital image techniques will be useful.
2. **To consider case studies of major failures and successes.** "Success has many parents; failure is an orphan." Much can be learned from failures; sometimes more than from successes, but most people are very reluctant to discuss those failures. We hope case studies, both positive and negative, are included in future guides.
3. **To research additional references.** The three remote sensing applications keys have gaps in the references available to resource mangers who want to learn more about particular applications. In some cases this is because of lack of time; in others, because there has been very little work done with a specific sensor in a specific region. We solicit references from installation managers who know of journal, article, or other source information not included in the bibliography.
4. **To consider compiling additional information on multispectral video vendors.** This field is changing rapidly. Sensors are moving rapidly from research and/or development to field implementation. Installation resource managers willing to put up with the frustrations of applied research may find opportunities to acquire imagery for their installations for a substantially lower cost than that of a mature technology. *Photogrammetric Engineering and Remote Sensing* is a journal that details new developments in this field.
5. **To describe capabilities of the Airborne Visible-Infrared Imaging Spectrometer Sensor (AVIRISS).** This sensor has been used to acquire large amounts of data very inexpensively. It may be described in a future edition of this guide, but was judged less useful than the sensors we did describe.
6. **To add Indian, Japanese, and other recently introduced satellite sensors.** These relatively new sensors have great promise, and will probably be described in future editions.
7. **To crosswalk to ATTACC and LCTA II.** Two ongoing efforts within the ITAM community are the Army Training and Testing Area Carrying Capacity (ATTACC) and the Land Condition Trend Analysis II (LCTA II). Integration of these efforts is key in providing comprehensive and complementary tools for training and testing land managers. At the publication date of this guide, the LCTA II report was still in draft; therefore, the crosswalk between these efforts will occur in the next version of this guide.
8. **To add your recommendations.** The best recommendations for additions, deletions and changes for future editions will come from working natural resource managers, trainers/testers, and MACOM staff. What do you want to see?

H. Acronyms

B&W	Black and White
CAP	Conservation Assistance Program
CCD	Charge Coupled Device
CD ROM	Compact Disk Read Only Memory
CIR	Color Infrared
CNES	Centre National d'Etudes Spatiales
DEM	Digital Elevation Model
DMSV	Digital Multispectral Video
DN	Digital Number
DoD	Department of Defense
EDC	EROS Data Center
EDC DAAC	EROS Data Center Distributed Active Archive Center
EMR	Electro Magnetic Radiation
EOSAT	Earth Observation Satellite Company
ERE	Effective Resolution Element
ERTS	Earth Resources Technology Satellite
FCIR	False Color Infrared
GIS	Geographic Information System
GLIS	Global Land Information System
GPS	Global Positioning System
GSD	Ground Surface Distance
http	Hyper Text Transportable Protocol
HRV	High Resolution Visible
IFOV	Instantaneous Field of View
IFSAR	Interferometric Synthetic Aperture Radar
IR	Infrared
IRS	Indian Remote Sensing
LCTA	Land Condition Trend Analysis
LISS	Linear Imaging Self Scanning
MIR	Mid Infrared
MS	Multispectral
MSS	Multispectral Scanner
NAPP	National Aerial Photography Program
NHAPP	National High-Altitude Photography Program
NTP	Notice to Proceed
nm	Nanometer (10 -9)
Pan	Panchromatic (i.e. black and white)
SAR	Synthetic Aperture Radar
S/N	Signal to Noise
SOW	Statement of Work
SPOT	Systeme Pour l'Observation de la Terre

SWIR	Short Wave Infrared
TES	Threatened and Endangered Species
TM	Thematic Mapper
*u*m	Micrometer (10 -6)
USGS	United States Geological Survey
WFS	Wide Field Sensor
WWW	World Wide Web
XS	Multispectral

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